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OPERATIONALLY EFFICIENT PROPULSION SYSTEM STUDY (OEPSS) DATA BOOK

Volume I – Generic Ground Operations Data

Prepared for
Kennedy Space Center
NAS10-11568

Prepared by
Raymond J. Byrd

April 24, 1990

Rocketdyne Study Managers: G. S. Wong/G. S. Waldrop
NASA, KSC Study Manager: R. E. Rhodes

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16. Abstract

This study was initiated to identify operations problems and cost drivers for current propulsion systems and to identify technology and design approaches to increase the operational efficiency and reduce operations costs for future propulsion systems. To provide readily usable data for the ALS program, the results of the OEPSS study have been organized into a series of OEPSS Data Books as follows: Volume I, Generic Ground Operations Data; Volume II, Ground Operations Problems; Volume III, Operations Technology; Volume IV, OEPSS Design Concepts; and Volume V, OEPSS Final Review Briefing, which summarizes the activities and results of the study. This volume presents ground processing data for a generic LOX/LH_2 booster and core propulsion systems based on current STS experience. The data presented includes: top logic diagram, process flow, activities bar-chart, loaded timelines, manpower requirements in terms of duration, headcount and skill mix per operations and maintenance instruction (OMI), and critical path tasks and durations.

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FOREWORD

This document is part of the final report for the Operationally Efficient Propulsion System Study (OEPSS) conducted by Rocketdyne Division, Rockwell International for the AFSSD/NASA ALS Program. The study was conducted under NASA contract NAS10–11568 and the NASA Study Manager is Mr. R. E. Rhodes. The period of study was from 24 April 1989 to 24 April 1990.

ABSTRACT

This study was initiated to identify operations problems and cost drivers for current propulsion systems and to identify technology and design approaches to increase the operational efficiency and reduce operations cost for future propulsion systems. To provide readily useable data for the ALS program, the results of the OEPSS study have been organized into a series of OEPSS data books as follows: Volume I, Generic Ground Operations Data; Volume II, Ground Operations Problems; Volume III, Operations Technology; and Volume IV, OEPSS Design Concepts.

ACKNOWLEDGMENT

The author wishes to express sincere thanks to Kennedy Space Center (KSC) Lockheed Space Operations Company personnel for providing the source of data used to derive the OEPSS generic vehicle processing operations contained in this volume. The assistance was provided in a quick, friendly, and professional manner. Even though much of the data was noted as not fully mature and in early stages of development, this OEPSS volume benefited immensely from its availability.

Special thanks is extended to Mr. Pat Scott, Manager, Liquid Rocket Booster Integration Study and Ms. Sue Scobby, Manager, Special Projects, for providing access to the data, and to Messrs. Lee Coppit, Jim Keathy, Russ Pierce, John Poppa, Mike Steffanovic, and others, who made time to work up special data requests and took time to handcarry the raw data for the author's timely use.

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1.0 INTRODUCTION

1.1 BACKGROUND

Traditionally launch vehicles have been designed with flight performance as the primary design driver. This approach has produced outstanding accomplishments in space. However, this approach does not take into consideration operational requirements needed to support the operation of the launch vehicle and has resulted in very costly and inefficient ground checkout and launch activities. Recent studies have clearly shown that the operational facilities, vehicle ground checkout, and launch requirements are driven by vehicle design. Launch system life cycle cost evaluations also have highlighted a need to emphasize ground operations during space vehicle conceptual design, if the ultimate goal is to develop a routine and cost–effective space transportation system.

In general, space vehicle design has utilized a nonintegrated approach. For example, space propulsion systems have been developed in a manner which has separated the engines from the rest of the propulsion systems. The tankage, pressurization, engine feed, and purge systems have been provided by one contractor while the engines were provided by another. The fluid subsystems have also been designed separately. The installation of these elements into the vehicle has resulted in many compromises which directly influence vehicle performance and ground operations. This nonintegrated, independent approach to propulsion and fluid systems design adds complexity and additional components with associated weight and processing time penalties. These inefficiencies can be significantly reduced if the engines and fluid systems are integrated with each other and into the overall vehicle design.

Figure 1–1 graphically portrays the traditional process of propulsion system development: a serial process with launch operations involvement occurring last, at the bottom of the totem pole. The OEPSS is dedicated to the interactive process shown, where all elements interact from the beginning. This interactive process is equivalent to the Total Quality Management (TQM) concept wherein, like quality, operational requirements start with the design and are not an afterthought.

1.2 THE REQUIREMENT

The pressing need for TQM during propulsion development is further illustrated by portraying the complex, interdependent functions necessary to support the launch site ground processing. Figure 1–2 shows the numerous functions necessary to support vehicle flight systems processing, providing insight to this complexity. Figure 1–3 further illustrates the great complexity associated with the launch operations support structure.

Launch site experience has repeatedly and clearly shown that operations is a major cost driver in the launch vehicle life cycle cost. Therefore, the lessons of complex and costly operational problems must be learned and corrected before a cost–effective launch vehicle and routine access to

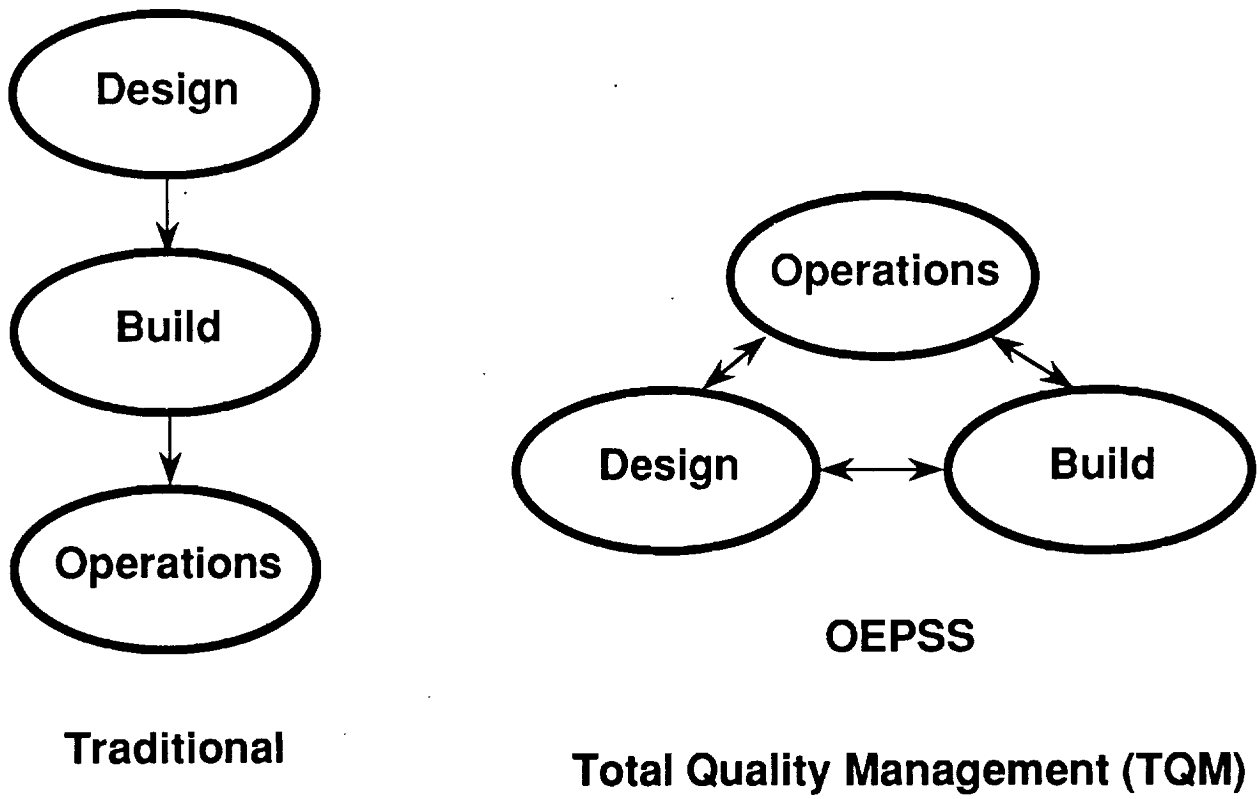

Figure 1-1. Propulsion System Development Process

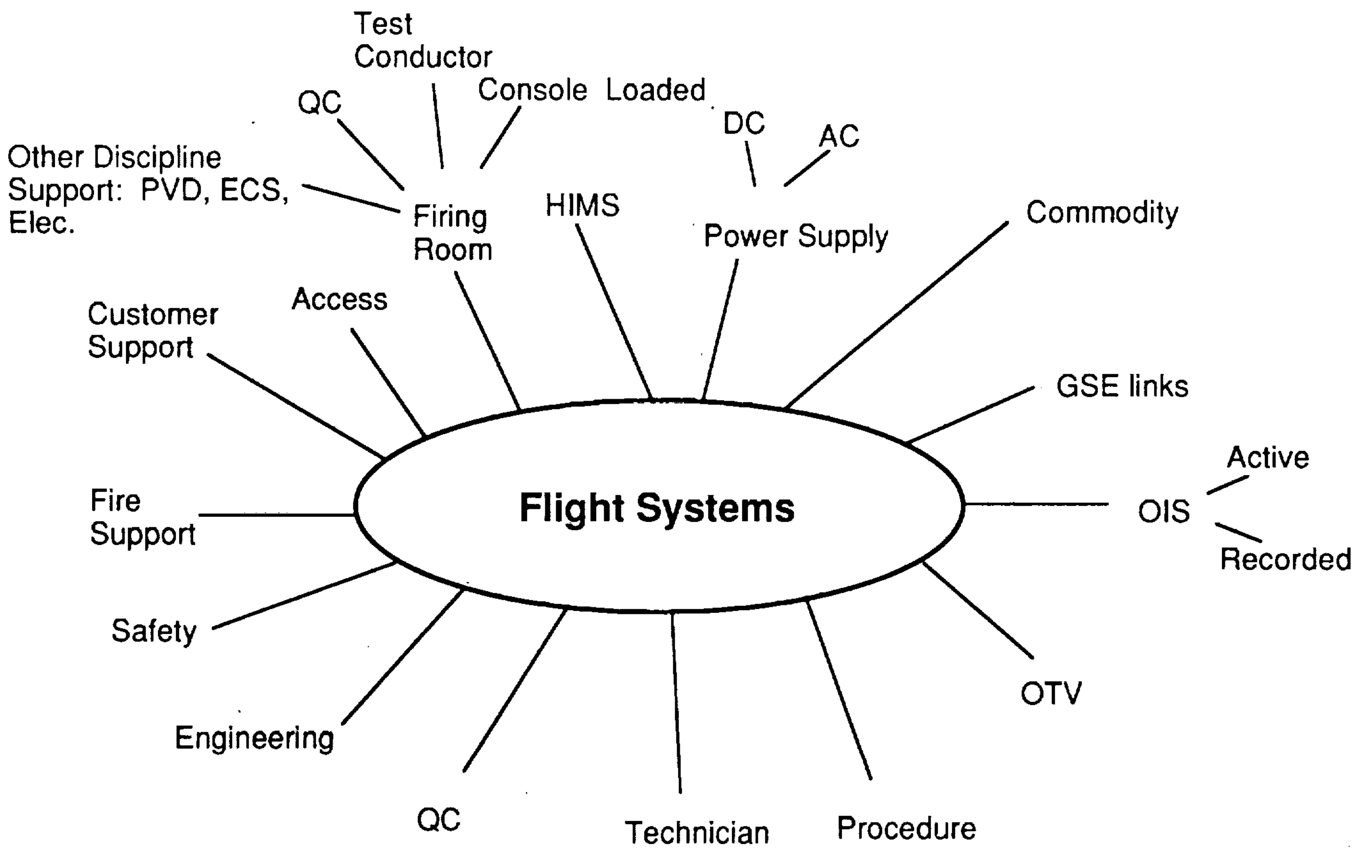

Figure 1–2. Launch Site Systems

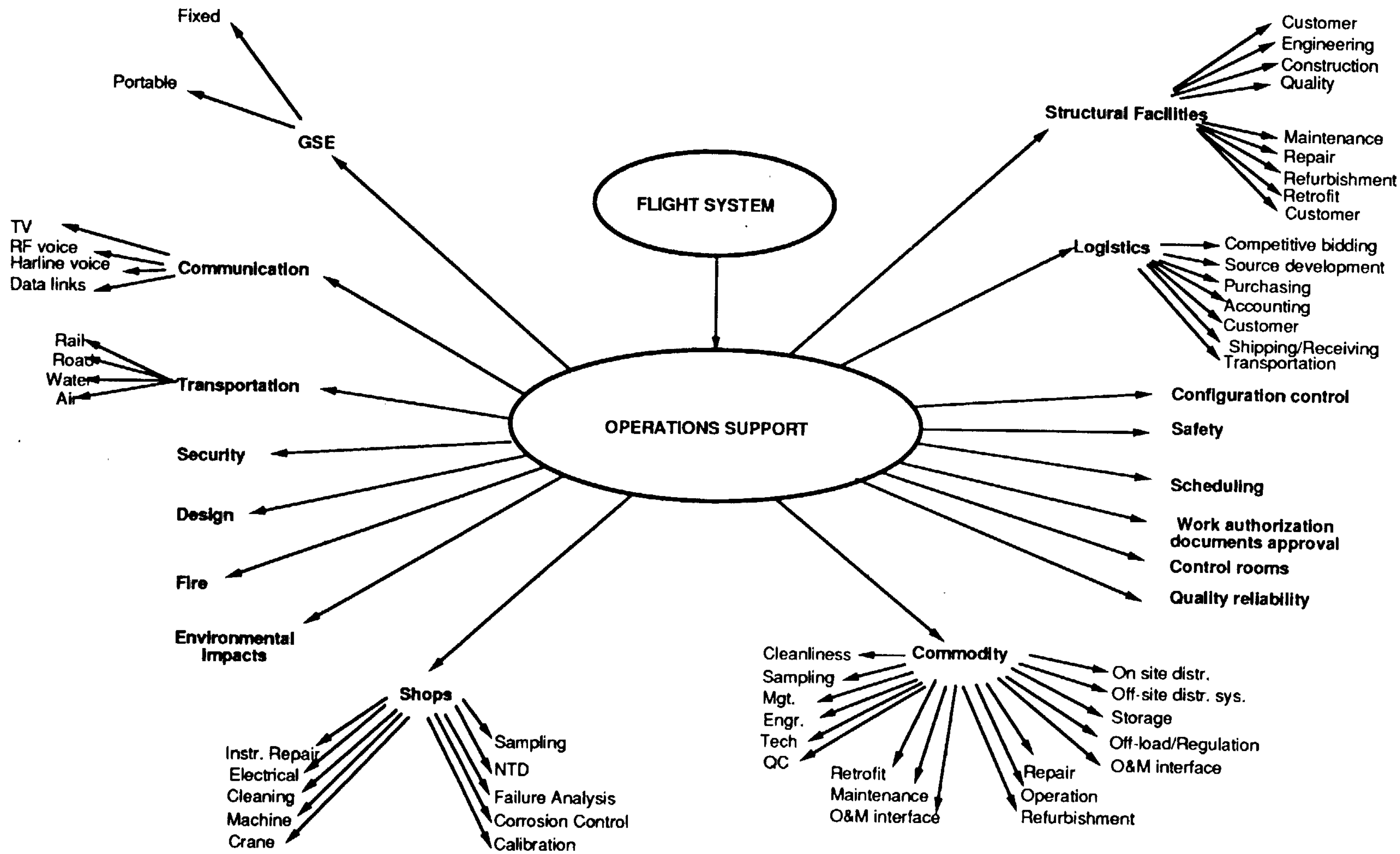

Figure 1–3. Launch Operations Support Structure

space can be achieved. Figure 1-4 presents the major problem areas where the development of operations criteria and systems requirements must be addressed in the vehicle design to provide:

- Low cost
- Simple systems
- Robust design
- High launch rate capability
- Greatly improved operability and maintainability (technician-level operations)

1.3 THE GENERIC VEHICLE – A DESIGNER'S DATA BASE

This volume fulfills one of the principal OEPSS study requirements. It provides significant ground processing time and manpower data for a generic vehicle, using real contemporary related information from systems possessing most of the generic salient characteristics. This information and format have the goal of allowing future systems designers to understand more easily the magnitude of resources at the operations and maintenance instruction level necessary to process and initiate their designs.

This volume, therefore, defines a conceptual generic baseline propulsion/fluid system configuration which can be used as a reference in evaluating newly generated designs. Each of the nine data chapters presents a similar collection of tabulations and charts that identify ground processing tasks to the operating procedure level, task performance sequence/hierarchy (logic diagrams), manpower, skill codes, skill mix, and critical path tasks with durations.

1.4 PROCESS DURATIONS AND MANPOWER

This volume also presents a large quantity of data which can be categorized generally as identification of processes, their durations, and manpower. Much of it has been derived from Shuttle Processing Contractor (SPC) planning and scheduling systems; notably, the Computer Aided Planning and Scheduling System (CAPSS). It is, therefore, generic, success-oriented scheduling data based on experience. It is not "actuals" as the SPC does not require cost center data acquisition at the operating procedure or system level.

For this reason, it is worthwhile to note in Tables 1-1 and 1-2 the "scatter" of high-level processing durations averaged over a number of pre-STS 51L launches. The objective here is to show the historical variation to be expected in a nonproduction, nonroutine processing environment. Durations can vary widely, even in the post-Challenger era.

Manpower is also a large data factor in this volume. In most cases, the skill mix data are for technicians and on-site quality inspectors. To gain a better understanding of total vehicle processing headcount and prime skill mix ratios, Table 1-3 lists that information circa 1987.

Headcount for FY 1990 has increased to about 7,400 attended by a slight shift in skill mix ratio toward systems engineering and quality/safety functions. These data, of course, do not address payload or base operations contracts and their headcount.

- **Vehicle processing/launch preparation**
  - Systems not readily serviceable
  - Too many people
  - Too much time
  - High cost
- **Ground operations and support**
  - Vehicle preparation
  - Personnel evacuation
    - Hypergols/ordnance
  - Complex vehicle trail
    - Multiple handling/hazardous rotation/high lifts
  - Multiple, complex support facilities and GSE
    - Large operational and maintenance headcount
    - Large material investment

Figure 1–4. The Operational Problem – Lessons Learned

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Table 1-1. STS Integrated Vehicle Servicing – KSC/VAB

Mission	Manhours
ST-14	12,700
ST-17	1,500
ST-19	2,800
ST-20	2,100
ST-23	2,000
ST-24	3,000
ST-25	5,100
ST-26	2,600
ST-27	3,300
ST-28	4,400
ST-30	2,100
ST-31	2,400
ST-32	3,700
ST-33	3,200

Sample average: 3,636

Table 1-2. STS Vehicle Test and Launch Operations – KSC/ Launch Pad

Mission	Manhours
ST-14	25,400
ST-17	14,500
ST-19	13,300
ST-20	8,300
ST-23	15,500
ST-24	19,200
ST-25	22,800
ST-26	14,300
ST-27	19,600
ST-28	16,500
ST-30	13,100
ST-31	12,000
ST-32	8,500
ST-33	20,200

Sample average: 15,943

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Table 1-3. SPC Skill Mix (October 1987)

Skills	Headcount	%
Management	526	9.2
Engineers (except Software and Test Conductors)	1,281	22.5
Command, Control, Information		11.8
• Programmers, Software Engineers, Computer Operators	378	
• Planners/Schedulers	293	
Flight Vehicle and Facilities (Crafts)		24.4
• Electrical/Electronic/ Communications	504	
• Mechanical/TPS/Fabrication	832	
• Logistics Storekeeper/ Expediters/Drivers	57	
Untabulated Administrative		32.1
• QA, Safety, Secretarial, Analysts, Clerks, Security, Business, Human Resources, etc.	1,828	
	5,699	100.0

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2.0 OEPSS GENERIC LAUNCH VEHICLE DESCRIPTION

This section defines the "generic launch vehicle" configuration baselined as a comparator for developmental propulsion concepts. Figure 2-1 describes the generic propulsion system. The pictorial portion is not intended to imply a specific physical arrangement of the stages (tandem, piggyback, parallel, etc.). It is important that the generic baseline truly represents today's state-of-the-art design practices and ground operations to avoid bias in the evaluation of future concepts.

The generic vehicle has been conceived and modeled through ground processing to provide designers of new concepts with a contemporary credible data base for comparison against those new concepts. In most cases, the generic components use extracted KSC/shuttle ground processing data not previously available at the operating procedure level. Tasks, durations, manpower, and interactive sequence are directly indicative of the complex relationships between vehicle/systems configurations and ground processing requirements established in accord with Operations Maintenance Requirements and Specification Documents, safety, and reliability concerns.

2.1 GENERIC BASELINE VEHICLE PROPULSION SYSTEM

The baseline launch vehicle propulsion system consists of a recoverable orbit vehicle, partially expendable core, and expendable boost vehicles. The orbit vehicle will have an orbit and attitude adjustment system utilizing hypergolic propellants. The core vehicle will be similar to the shuttle main propulsion system, using LO_2/LH_2. The boost vehicle will also use LO_2/LH_2 as propellants.

The core and boost vehicles have several subsystems. The major subsystems are:

1. Fill and drain for loading propellants from a ground system. Separate fill and drain systems will be required for each stage and will include self-sealing disconnects, fill/drain valves, and propellant liquid level controls. In the baseline, the LO_2 tanks will be forward of the fuel tanks and will require an anti-geyser system, such as a ground-supplied helium bubbling system.

2. Preconditioning system to precondition the main engines for start, utilizing recirculation pumps powered from a ground electrical system and/or bleed system, and all required valves, including prevalves, for each engine.

3. Pressurization and venting systems, requiring a single vent/relief valve for each tank, opened for propellant loading. For engine burn, pressurants supplied by the engines, with flow control valves and/or orifices, will maintain tank pressures to supply required net positive suction pressure (NPSP) at turbopump inlets.

4. Purging and pneumatics systems to provide on-board helium storage for valve actuation and engine purging.

5. Hydraulic system for engine gimballing.

6. Main engine systems LO_2/LH_2 are turbopump-fed with limited throttle and single start capabilities. Engines have augmented spark ignition. The engine system also includes required supervisory avionics and hydraulic/pneumatic valve actuators.

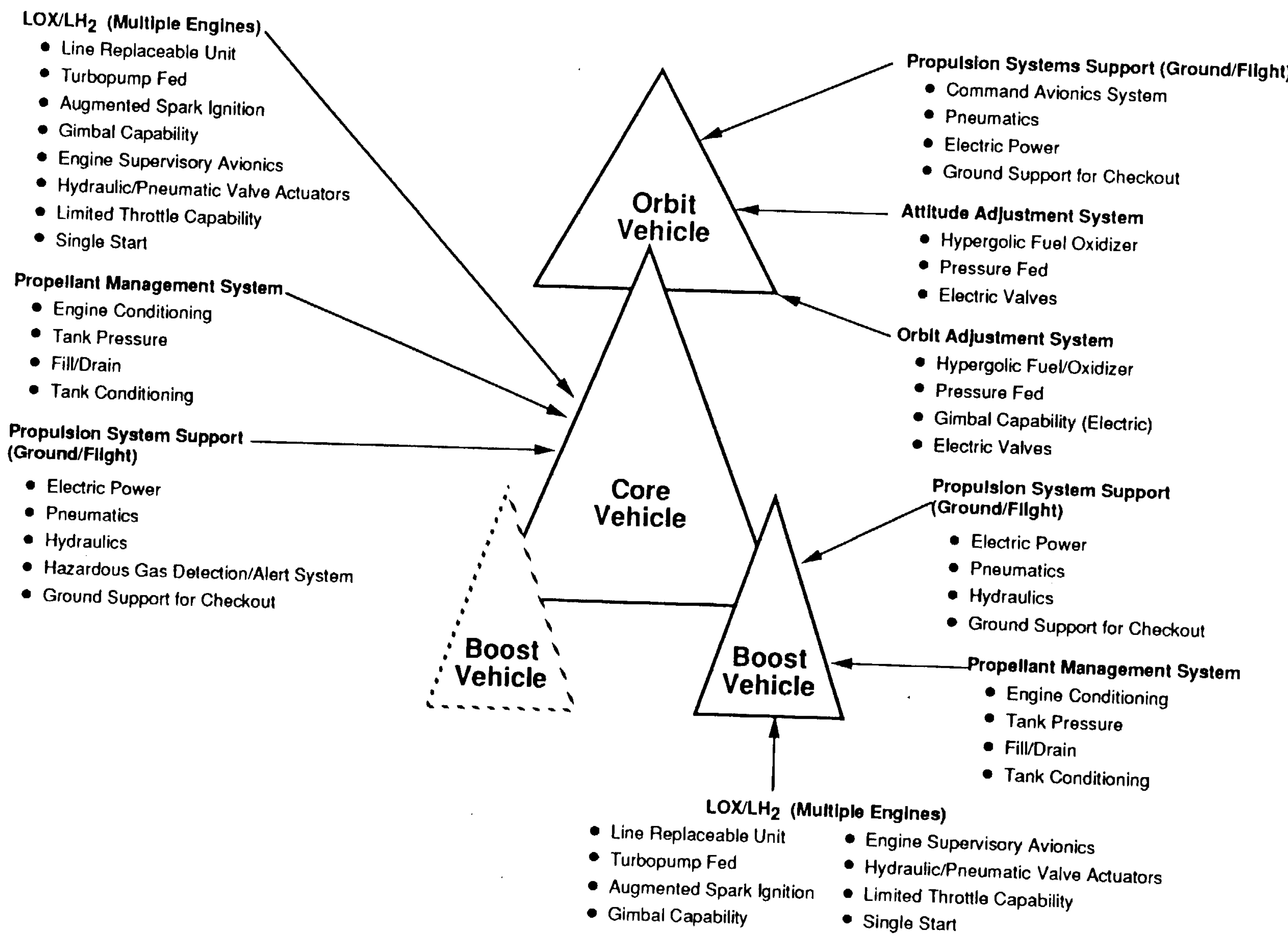

Figure 2–1. OEPSS Generic Launch Vehicle

Figure 2–1 shows a generalized representation of the OEPSS generic vehicle. A derivative of the shuttle (liquid boosters replacing the solids) provides the major input because data regarding its influence on operations are more readily available (processing timelines, manpower, facilities, etc.)

2.2 GENERIC GROUND OPERATIONS REQUIREMENTS

For the generic baseline vehicle configuration and propulsion system, the operational requirements are established for various aspects of launch operations as depicted in Figure 2–2. The SPC Computer Aided Planning and Scheduling System (CAPSS), KSC "Integrated Operations Assessments," KSC "Program Master Schedule" 11–day/72–hr schedules, Operations and Maintenance Instructions (OMIs), and other documentation were used to establish flow timeline requirements, associated manpower for test, checkout, and servicing. Prime facilities are also noted.

Development of launch site ground operations, tests, checkout, and servicing requirements are restricted to propulsion systems. Figure 2–3 is a flow chart of a typical launch operation from receipt of hardware to checkout of individual subsystems and the integrated vehicle, launch, and orbit vehicle recovery. The sections in this volume describing the various launch operations are also noted in Figure 2–3.

Following sections of this volume provide, in general:

1. Logic diagrams showing task–performance sequence and hierarchy
2. Operating procedure (OMI)–level activities lists with durations, headcount, and skill mix
3. Critical path tasks lists with durations.

These data are provided in nine separate sections (3.0 through 11.0) for the generic vehicle components ground processing.

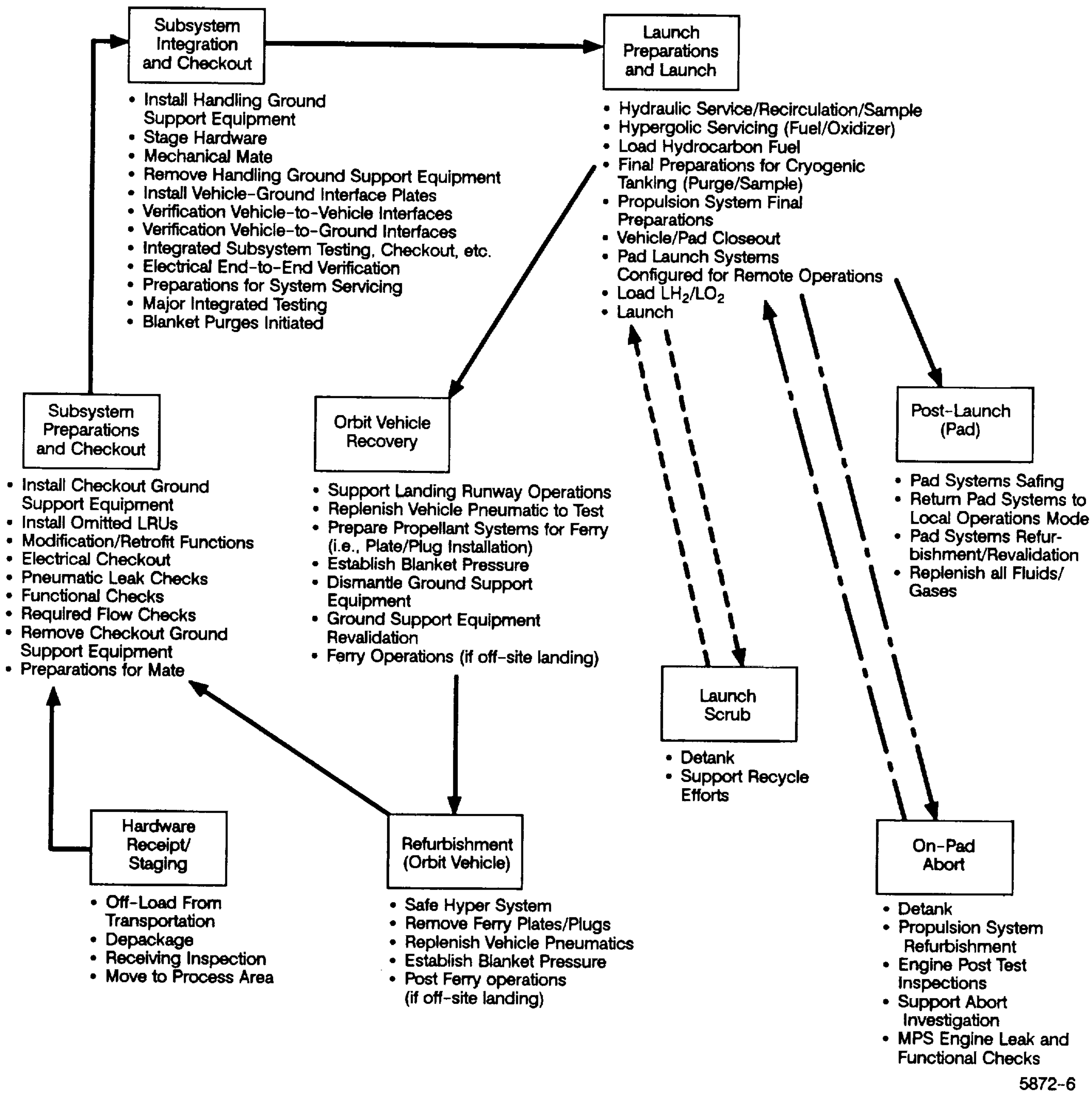

Figure 2-2. Launch Operational Requirements

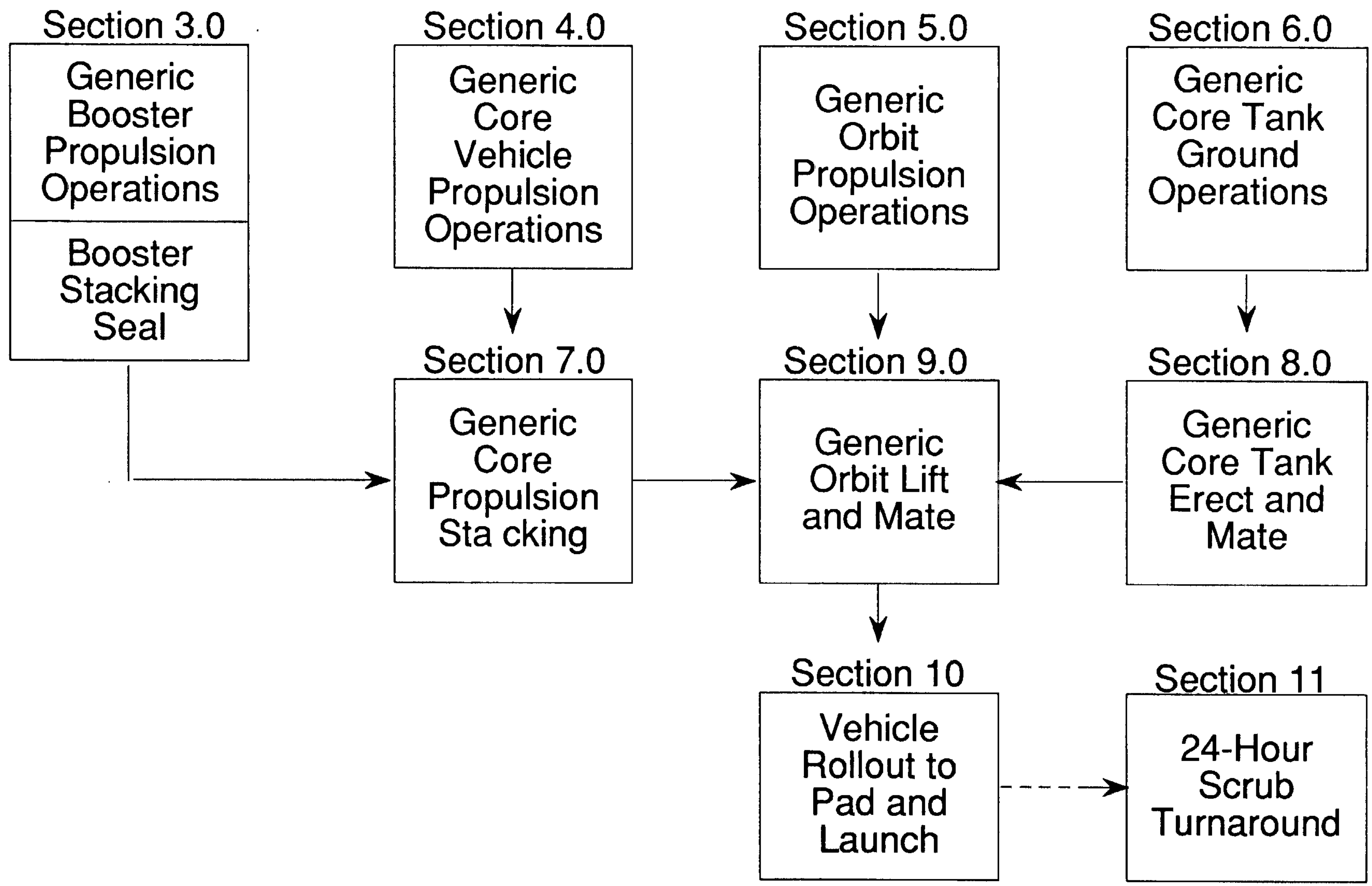

Figure 2–3. Generic Vehicle Ground Processing

3.0 GENERIC BOOSTER GROUND OPERATIONS (EXPENDABLE LO_2/LH_2 STAGE)

The generic baseline booster is a LO_2/LH_2 expendable stage. Data presented herein for its ground processing are extracted from the Liquid Rocket Booster (LRB) Integration Study conducted by LSOC to assess KSC impact resulting from the theoretical phase–in of LRBs in the shuttle program. The data are quite comprehensive and selected to provide designers with processing insight into a generic liquid propellant booster. The format is somewhat different from subsequent sections, but similar in scope and data content relative to OMI–level schedules, durations, headcount, and skill mix.

These LRB data possess one significant variation from the OEPSS generic booster configuration. The LRB uses electromechanical actuators rather than the hydraulic system specified for the OEPSS baseline. However, the LRB study conclusion, detailed in this section, reveals a small difference in headcount or processing schedule; only a well–described variation in skill mix. The OEPSS treatment of this section is to present it "as–is." Data are adequate for designers to edit and manipulate freely to assess their own designs, EMA or hydraulic.

The impact of hydraulic systems on ground operations is presented in OEPSS Concern 2 in Volume 2 of this study. As an example, during the period from October 10, 1988 through March 14, 1989, processing for mission STS–29R, (orbiter Discovery) basic hydraulics procedures were officially opened for a variety of significant support operations 199 times. Hydraulics systems were run at least 45 times with a total run time exceeding 150 h. The impact of hydraulics is an all pervasive and encroaching handicap to ground operations.

The following is a list of topics covered in this section to acquaint users with the scope of data on their potential use.

- 3.1 Acronyms and Abbreviations
- 3.2 KSC/LRB Integration Study — database
- 3.3 Loaded Timelines — ground rules for time line and manpower development including generalized skill mixes
- 3.4 Skill Mixes — detail skill mixes and shift assignments
- 3.5 LRB Processing Manpower — resultant manloading for LRB
- 3.6 STS WBS Manhours (Reference) — historical manhour variation for ground processing by prime WBS, i.e., SRB, VAB, and pad processing
- 3.7 LRB Activities Barchart — task list and waterfall schedules
- 3.8 LRB Technician Manpower — detail manhours by skill and OMI
- 3.9 LRB Headcount by Location and OMI — detail headcount by OMI and facility location

- 3.10 Generic LRB Process Flow — a major summary barchart of LRB activities from barge delivery to launch

3.1 ACRONYMS AND ABBREVIATIONS

A/B	airborne
ARTEMIS	Accounting, Reporting, Tracking, and Evaluation Management Information System
ASSY	assembly
BAO	Boeing Aerospace Operations (KSC)
BOC	base operations contractor
CDDT	countdown demonstration test
C/O	closeout; checkout
CPM	critical path method
CS	Civil Service
ECS	Environmental Control System
EG&G	KSC base operations contractor
ELV	expendable launch vehicle
ES	Electrical System
ET	external tank
FAC	facility
F&B	fill and bleed
F&D	fill and drain
FLT	flight
FY	fiscal year
GN_2	gaseous nitrogen
GN&C	guidance, navigation, and control
GOX	gaseous oxygen
GRD	ground, also GND
GSE	ground support equipment
GTSI	Grumman Technical Services, Inc.
H_2	hydrogen
HDP	holddown post
He	helium
HPF	Horizontal Processing Facility

HYPER	hypergolic
I/F	interface
ILC	initial launch capability
INST	instrumentation
INTEG	integration, also INT
IOC	initial operational capability
KSC	Kennedy Space Center
LH_2	liquid hydrogen
LN_2	liquid nitrogen
LO_2	liquid oxygen, also LOX
LPS	launch processing system
LRB	liquid rocket booster
LRU	line replaceable unit
LSOC	Lockheed Space Operations Company
mh	manhours
MLP	mobile launch platform
MP	manpower, also MHRS
MTI	Morton–Thiokol, Inc.
N_2	nitrogen
NASA	National Aeronautics and Space Administration
NASP	National Aerospace Plane
NDE	nondestructive evaluation
NDT	nondestructive test
NF	nose fairing
O&M	operations and maintenance
OEPSS	Operationally Efficient Propulsion System Study
OMI	operations and maintenance instruction
OMRSD	Operations Maintenance Requirements and Specifications Document
OPS	operations
ORB	orbiter
PAWS	Pan Am World Services, Inc.
PMN	program model number

PP&C	program planning and control
PR	problem report
PRESS	pressurization
PROP	propellant
P&W	Pratt and Whitney Aircraft
PWR	power
PWO	program work order
QA	quality assurance
QC	quality control
QD	quick disconnect
RIC	Rockwell International Corporation
RPSF	Rotation, Processing, and Surge Facility
RSS	Rotating Service Structure
SCAPE	self–contained atmospheric protective ensemble
SEG	segment
SEP	separation
SGOE/T	Shuttle Ground Operations Efficiencies/Technologies Study
SPC	shuttle processing contract(or)
SPDMS	Shuttle Processing Data Management System
SRB	solid rocket booster
SRM	solid rocket motor
SRSS	Shuttle Range Safety System
SR&QA	safety, reliability, and quality assurance
SSV	space shuttle vehicle
STD	standard
STS	Space Transportation System
T&C/O	test and checkout
T–O	liftoff time
TLM	telemetry
TOPS	technical operating procedures
TPS	Thermal Protection System
TSM	tail service mast

TVC	thrust vector control
UMB	umbilical
USAF	United States Air Force
VAB	Vertical Assembly Building
WAD	work authorization document
WBS	work breakdown structure

3.2 LRB INTEGRATION DATA BASE

Input data for this section were developed for LSOC-KSC. The ratios of support technicians for the orbiter were used because of the multiple liquid engines and associated control mechanisms. These ratios were further adjusted to reflect the differences in complexity between the LRB and the orbiter.[1]

Manpower estimates[2] are based on the concept that technicians will be stationed and do not move with the booster during the flow process. Initial staffing would not have to be as high as fully operational staffing because of the low relative launch rate. There would be a ramp-up over 5 years beginning with start-up. Thus far the discussion has centered on the required number of hands-on technicians required to support the booster flow.

Manpower requirements are based only on scheduled routine tasks. There is no allocation for requirements generated by nonroutine work. Best estimates based on other LRB/ET technology place this at 20% of scheduled tasks.

Fourteen flows representing a relatively stable period or work history were selected as a baseline, during a time when the launch rate had reached 10 per calendar year. This is a good approximation of a rate of 14 per year as projected for a fully operational LRB system. The time in each facility adds up to a total processing time of 58 days (51 work days) as shown in Figure 3-1. The critical path driver is MLP/VAB/Pad availability. Time at the Horizontal Processing Facility was maximized to allow smoothing of high manpower peaks, but was limited to 18 days by the maximum flow rate of 14 per year. Original LRB ARTEMIS manning projections were based on a steady flow with perfect leveling. Once the required number of hands-on technicians was established, based on the assumption that the SPC contractor would process the LRB, current ratios of support-to-technician that exist today were applied to establish support requirements (see Figure 3-2).

The number of technicians and support personnel required for ILC would not be as large as that required for IOC. A smaller number (50%) would be sufficient for the first year. This is possible

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[1]Reference: LSOC LRB Integration Study; Contract NAS10-11475, Volume V of V, Section 6, Final Report, Phase 1, November 1988.

[2]Reference: LSOC LRB Integration Study, Contract NAS10-11475, Volume III of V, Section 6, Final Report, Phase I, November 1988.

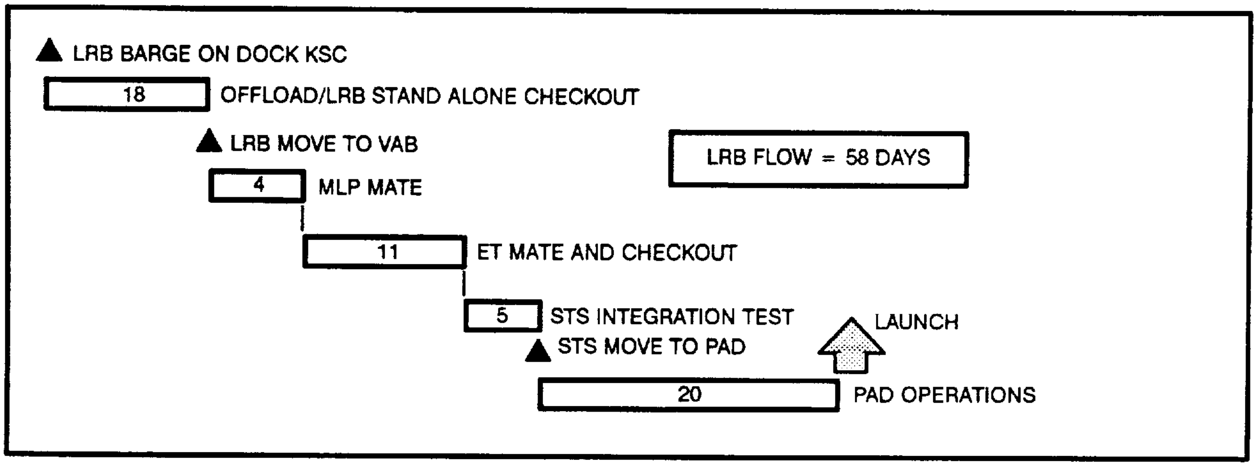

Figure 3-1. Generic LRB Process Flow

because the processing time has been increased to accommodate the start-up learning curves and initially lower launch rate.

3.3 LOADED TIMELINES

The baseline generic flow did not attempt to look at peak loading of time for facility flow constraints. It used a fully averaged number based on total flow period, i.e.,

- Flow manhours 26,110/flow time (51 days x 8 hr) = 64 technicians.

A second approach was made using manhours versus time in facility flow constraints with averaged headcount.

- HPF manhours 11,066/days available (18 x 8 hr) = 77 technicians
- VAB manhours 5,336/days available (20 x 8 hr) = 33 technicians
- PAD manhours 9,708/days available (20 x 8 hr) = 61 technicians.

The assumption has been made that shifts will vary by location — in some part driven by the critical nature of the operation. Figure 3-3 illustrates the number of shifts and days worked at each location. The VAB is the only facility where three shifts — 7 days a week — are forecast from day one of the program. No attempt has been made to determine manning by shift. This is a very complex problem and will require a knowledge of technical work document content before such details can be credibly approached. This information is dependent on LRB final design characteristics.

3.4 SKILL MIX

Figure 3-4 shows the skill relationships predicted for the LRB. The LRB skill mix was based on an examination of predicted work tasks in the ARTEMIS projection used for the baseline.

Skill Mix	Ratios	Manhours	Manpower
Technicians	1.0	26,110	64
Engineering	0.89	23,238	57
Fac & Gnd Support	1.14	29,765	73
Logistics	0.53	13,839	34
Quality	0.38	9,921	24
Safety	0.08	2,088	5
PP&C	0.22	5,744	14
Overhead	0.42	10,967	27
	0.71	18,538	45
Subtotal	5.37	140,210	343
Base Support	1.60	32,090	77
NASA KSC	1.92	38,508	94
Totals	8.89	210,808	514

Comments and assumptions:

- Manpower based on multiflow environment (baseline + 30%)
- Manpower based on a 51 working day flow
- Manpower is calculated 8 hours a day times 51 days divided into manhours

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Figure 3-2. LRB Processing Manloading (51 Day Flow)

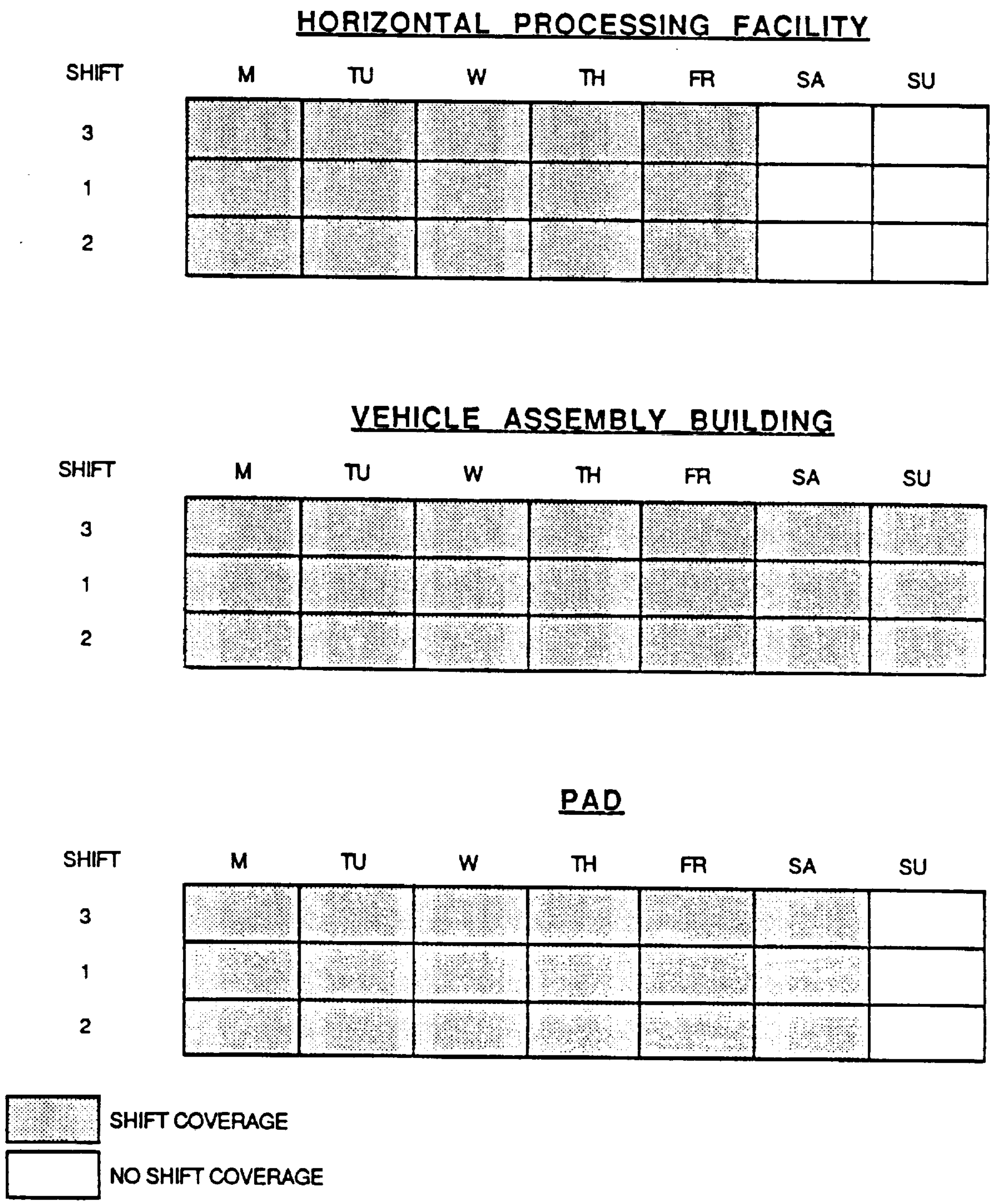

Figure 3–3. Shift Work

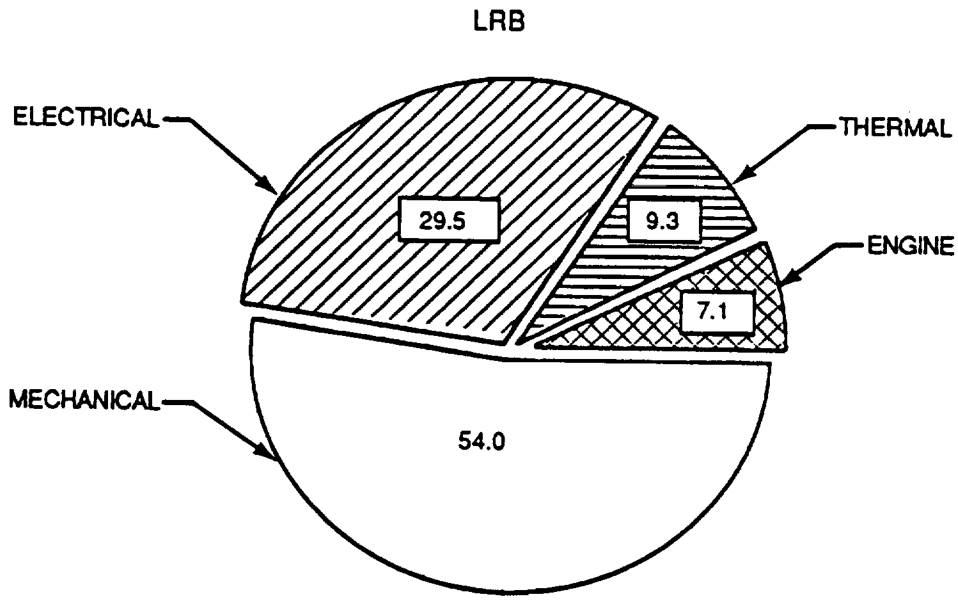

Figure 3–4. Technical Skill Mix

Another area of question is the low ratio of engine technicians to mechanical/electrical technicians, especially in light of the fact there are four engines per booster. In assessing tasks, any job that was related to TVC/flight controls/telemetry was assigned to the electrical skill group rather than engines. Second, any tasks related to plumbing attached to the engines was given to mechanical. If these assessments were reversed, both mechanical and electrical skills would increase appreciably. The actual percentages will probably be somewhere in between. Section 3.9 provides the listing of OMIs and skill mix that will allow a designer to reapportion the skill mix to accommodate a specific design.

No manhours are allocated for nonroutine work generated by problem reports (PRs). These are estimated to be in the area of 20% of routine tasks. The largest portion of this would probably be generated by engine/engine LRU changes and TPS repair work.

The pump–fed LO_2/RP–1 engine was used as the baseline for manpower estimates and skill mixes. The pump–fed LO_2/LH_2 booster is considered very similar with respect to HPF manhours and skill mixes, as well as the VAB. The main difference would be PAD servicing, with a possible longer fueling time since the RP–1 loading could be accomplished prior to countdown in parallel with other tasks. The increased amount of hydrogen required for combined generic core stage and booster will increase fueling time significantly.

3.5 LRB PROCESSING MANPOWER

Tables 3–1 and 3–2 provide manloading and skill mix summary for the LSOC LRB, based on an alternative 53–workday schedule, varying as expected from similar data shown for a 51 workday schedule in Figure 3–2 and discussed in Section 3.3. Further useful data is the technician manhour breakdown showing the division between processing, VAB, and PAD.

Table 3-1. **LRB Processing Manloading**

Skill Mix	Ratio	Manhours	Manpower
Technicians	1.00	20,056*	47
Engineering	0.89	17,850	42
Fac & Gnd Sup	1.14	22,864	54
Logistics	0.53	10,630	25
Quality	0.38	7,621	18
Safety	0.08	1,604	4
PP&C	0.22	4,412	10
Overhead	0.42	8,424	20
LPS	0.71	14,240	34
Subtotal		107,701	254
Base Support	1.60	32,090	76
NASA/KSC-CS	1.92	38,508	91
Subtotal		70,598	167
Total		178,299	421

Comments and assumptions:

1. Manpower based on 53-day generic LRB flow
2. Manpower calculated 8 h/day x 53 days and divided into manhours

*	Processing	11,744
	VAB	3,632
	PAD	4,680
		20,056

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Table 3-2. **Supplementary Data**

- Overall support ratios to technicians

  Shuttle: 4.37:1
- Shuttle scrub/recycle per day

  Technicians: 5,000 mh
  Support: 21,850 mh

  Total mh 26,850
- Scheduled to unscheduled maintenance ratio: 2.42:1

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3.6 STS WBS MANHOURS

Work breakdown structure data for the calendar year 1985 was selected as a reference baseline for development of LRB data. This period was used because it represents the highest launch rate and busiest work activity of any year in STS history (at this writing). Ten launches occurred during this time, which is the closest approximation to the projected 14 launches per year.

Tables 3–3, 3–4, and 3–5 show historical manhour data for ground processing of most of the STS flights from STS–14 through STS–33. Intent of the presentation is to provide designers with insight to the potential variables of ground processing manhours. The tables are segregated by major function/location and WBS, i.e., SRB processing, vehicle integration in the VAB, and launch operations at the PAD.

3.7 LRB ACTIVITIES BARCHART

Figure 3–5 is a four-page continuous barchart showing the generic, success-oriented 58-day ground processing flow for the LO_2/RP–1 LRB developed by LSOC for the LRB Integration Study. It presents OMI-level task designators (Activity Number), barchart schedule showing parallel and serial tasks, and overall 58-day timeline using 1-week time-scale divisions. It begins with LRB checkout cell preparations (prior to checkout) and shows all major processing activities all the way through rollout, countdown, and launch.

As noted earlier, processing time for either a LH_2 or RP–1 stage is surprisingly similar. The principal difference is for pad processing and countdown where cryogenic and hydrogen leakage concerns are dominant. For this reason, the LRB data presented here are recommended for use as data base for the OEPSS generic baseline booster. Designers studying this information will need to apply their own correction factors in this area.

The six-digit-plus-alpha Activity Number (Act. No.) is an arbitrary task number assigned to enable tracking and manipulation in ARTEMIS and the Computer-Aided Planning and Scheduling System (CAPSS). The last two digits and alpha suffix are used in following sections to designate the OMI-level tasks. This waterfall barchart provides a visual indication of tasks identity, hierarchy, and duration. Some of the prime nonpropulsion tasks have been crossed out in deference to the propulsion scope of this study.

This section is directly related to, and in support of, Sections 3.8 and 3.9 which delve into manpower, locations, skills, and manhours, in addition to task OMIs.

3.8 LRB TECHNICIAN MANPOWER

Each of the tasks in the ARTEMIS CPM charts (not presented here) was examined by the LRB Integration Study to determine required technician skills. Basic skill types of mechanical, electrical, engine, and TPS were established. Totals were compiled and the skill mix comparison charts developed. These data are also recommended for use in the OEPSS generic data base.

Table 3–3. SRB Processing Manhours (WBS 1.1.2.1)

Mission	SRB Process (mh)
STS–17	17,300
STS–19	19,800
STS–20	12,500
STS–23	13,900
STS–24	9,200
STS–25	14,100
STS–26	16,700
STS–27	16,000
STS–28	19,500
STS–30	15,900
STS–31	12,300
STS–32	10,700
STS–33	28,700
Sample Average	15,892

Table 3–4. Integrated Vehicle Servicing – VAB (WBS 1.1.4.1)

Mission	Integrated Service (mh)
STS–14	12,700
STS–17	1,500
STS–19	2,800
STS–20	2,100
STS–23	2,000
STS–24	3,000
STS–25	5,100
STS–26	2,600
STS–27	3,300
STS–28	4,400
STS–30	2,100
STS–31	2,400
STS–32	3,700
STS–33	3,200
Sample Average	3,636

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Table 3-5. Vehicle Test and Launch Operations — PAD (WBS 1.1.4.2)

Mission	Vehicle Test (mh)
STS-14	25,400
STS-17	14,500
STS-19	13,300
STS-20	8,300
STS-23	15,500
STS-24	19,200
STS-25	22,800
STS-26	14,300
STS-27	19,600
STS-28	16,500
STS-30	13,100
STS-31	12,000
STS-32	8,500
STS-33	20,200
Sample Average	15,943

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OMI is the designation for Operation and Maintenance Instruction-level task designator and not the actual assigned OMI number. The numbers for OMI are arbitrary assignments by planning elements to allow ease of tracking and manipulation of specific procedures and portions of OMI in ARTEMIS and the Computer-Aided Planning and Scheduling System (CAPSS). These are the last three alphanumeric symbols appearing in the Act. No. column of Figure 3-5.

Table 3-6 presents mechanical technician cumulative manhours by OMI and OMI duration. A further significant data breakdown by principal location (VAB, HPF and PAD) is also shown. Table 3-7 provides the same information for electrical technicians, as do Table 3-8 (engine technicians) and 3-9 (TPS technicians). Table 3-10 totals the foregoing technician data and displays it by skill percentage.

The total technician manhours shown below are directly comparable to the 26,110 shown in Figure 3-2 and further discussed in Section 3.3.

Mechanical	14,104
Electrical	7,852
Engine	1,872
TPS	2,432
Total	26,260

These data enable designers to compare accurately their own designs and processing tasks to that of the OEPSS generic data base by specific task, skill, and location — data never before available to the aerospace community in this fine a granularity.

3.9 LRB HEADCOUNT BY LOCATION AND OMI

These data were determined by the LRB Integration Study by examining each of the tasks in the ARTEMIS baseline CPM chart (not presented here) and allocating them by location. This allowed the establishment of manpower allocation by location. The OMI task numbers were used for identification. These data are also recommended for use in the OEPSS generic booster data base.

Table 3-11 is a further expansion on the technician data presented in Section 3.8. Specifically, it reslices the information to include shift quantities and presents the technician totals by location for the HPF. Table 3-12 and 3-13 present the same data for VAB and PAD locations, respectively.

OMI is the designation for Operation and Maintenance Instruction-level task designator as used in Sections 3.7 and 3.8. The numbers for OMIs are arbitrary assignments by Planning elements to allow ease of tracking and manipulation of specific procedures and portions of OMIs in ARTEMIS and the Computer-Aided Planning and Scheduling System (CAPSS). Hours are task duration. "Type" is skill, where M = mechanical, E = electrical, R = engine, and TPS = TPS.

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Table 3-6. LRB Mechanical Technician Manhours (Sheet 1 of 2)

OMI	HOURS	LOCATION	CUMULATIVE HOURS
048C	64	VAB	64
054C	48	VAB	112
050C	64	VAB	176
051C	80	VAB	256
150D	56	VAB	312
055D	336	VAB	648
250E	16	VAB	664
066D	16	VAB	680
056D	48	VAB	728
067D	32	VAB	760
155E	336	VAB	1096
059D	128	VAB	1224
164E	16	VAB	1240
166E	16	VAB	1256
156E	48	VAB	1304
167E	32	VAB	1336
159E	128	VAB	1464
061F	1056	VAB	2520
069F	48	VAB	2568
073F	256	VAB	2824
078F	80	VAB	2904
01A	84	HPF	2988
06A	64	HPF	3025
02A	80	HPF	3132
05A	72	HPF	3204
08A	64	HPF	3268
012B	112	HPF	3380
013B	32	HPF	3412
015B	32	HPF	3444
016B	32	HPF	3476
044B	640	HPF	4116
046B	288	HPF	4404
023B	256	HPF	4660
022B	144	HPF	4804
040B	320	HPF	5124
021B	96	HPF	5220
034B	384	HPF	5604
035B	144	HPF	5748
032B	64	HPF	5812
033B	128	HPF	5940
031B	192	HPF	6132
038B	1536	HPF	7668
036B	288	HPF	7956
037B	576	HPF	8532
301B	80	HPF	8612
047B	160	HPF	8772
053B	80	HPF	8852
070G	64	PAD	8916
071G	64	PAD	8980
072G	1344	PAD	10324
079T	160	PAD	10484
074G	192	PAD	10676

		SUBTOTAL	10676

Table 3-6. LRB Mechanical Technician Manhours (Sheet 2 of 2)

OMI	HOURS	LOCATION	CUMULATIVE HOURS
			10676
080T	80	PAD	10756
075G	288	PAD	11044
076G	64	PAD	11108
084H	132	PAD	11240
083H	16	PAD	11256
082H	16	PAD	11272
085H	168	PAD	11440
086H	144	PAD	11584
090H	192	PAD	11776
089H	32	PAD	11808
091H	48	PAD	11856
094H	96	PAD	11952
095H	240	PAD	12192
096H	32	PAD	12224
097H	48	PAD	12272
098I	360	PAD	12632
104H	96	PAD	12728
101H	96	PAD	12824
099H	160	PAD	12984
106H	192	PAD	13176
111H	96	PAD	13272
108H	32	PAD	13304
107H	32	PAD	13336
109H	128	PAD	13464
190I	640	PAD	14104

		TOTAL CUMULATIVE HOURS	14104

3.10 GENERIC LRB PROCESS FLOW

The LRB schedule summary of processing activities from barge delivery to launch is shown in Figure 3-6. This major summary schedule covers all the dedicated tasks in the model described in this section.

Table 3-7. LRB Electrical Technician Manhours

OMI	HOURS	LOCATION	CUMULATIVE HOURS
01A	84	HPF	84
07A	64	HPF	148
04A	64	HPF	212
019B	64	HPF	276
014B	32	HPF	308
017B	64	HPF	372
018B	64	HPF	436
020B	192	HPF	628
046B	288	HPF	916
024B	192	HPF	1108
026B	288	HPF	1396
027B	64	HPF	1460
029B	320	HPF	1780
030B	128	HPF	1908
025B	384	HPF	2292
115B	64	HPF	2356
042B	256	HPF	2612
043B	384	HPF	2996
114B	160	HPF	3156
047B	160	HPF	3316
053B	80	HPF	3396
151C	80	VAB	3476
049C	64	VAB	3540
057D	64	VAB	3604
065D	16	VAB	3620
058D	32	VAB	3652
064D	16	VAB	3668
060D	64	VAB	3732
157E	64	VAB	3796
165E	16	VAB	3812
158E	32	VAB	3844
160E	64	VAB	3908
061F	1056	VAB	4964
062F	48	VAB	5012
063F	96	VAB	5108
077F	640	VAB	5748
078F	80	VAB	5828
080T	80	PAD	5908
081H	48	PAD	5956
088H	48	PAD	6004
093H	32	PAD	6036
087H	192	PAD	6228
092H	96	PAD	6324
098I	360	PAD	6684
103H	64	PAD	6748
105H	48	PAD	6796
100H	288	PAD	7084
110H	32	PAD	7116
112H	96	PAD	7212
190I	640	PAD	7852
		TOTAL CUMULATIVE HOURS	7852

Table 3-8. LRB Engine Technician Manhours

OMI	Hours	Location	Cumulative Hours
039B	192	HPF	192
041B	224	HPF	416
047B	160	HPF	576
300B	16	HPF	592
102H	256	PAD	848
360H	384	PAD	1,232
190I	640	PAD	1,872
Total Cumulative Hours			1,872

Table 3-9. LRB TPS Technician Manhours

OMI	Hours	Location	Cumulative Hours
045B	1,280	HPF	1,280
350B	1,152	HPF	2,432
Total Cumulative Hours			2,432

Table 3-10. LRB Skill Mix by Percentage

Skill	Total (h)	Percentage
Mechanical	14,104	53.7%
Electrical	7,852	29.9%
Engine Technician	1,872	7.1%
TPS Technician	2,432	9.3%
Total	26,260	100.0%

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Table 3-11. LRB Headcount – Horizontal Processing Facility

OMI	SHIFT	HOURS		TECHS	TYPE	TASK HOURS	TOTALS
01A	3 shifts	(24 hrs	X	7 persons)	M/E	168	168
06A	4 shifts	(32 hrs	X	2 persons)	M	64	232
07A	4 shifts	(32 hrs	X	2 persons)	E	64	296
02A	5 shifts	(40 hrs	X	2 persons)	M	80	376
05A	3 shifts	(24 hrs	X	3 persons)	M	72	448
04A	4 shifts	(32 hrs	X	2 persons)	E	64	512
08A	4 shifts	(32 hrs	X	2 persons)	M	64	576
012B	2 shifts	(16 hrs	X	7 persons)	M	112	688
019B	2 shifts	(16 hrs	X	4 persons)	E	64	752
014B	1 shift	(8 hrs	X	4 persons)	E	32	784
017B	2 shifts	(16 hrs	X	4 persons)	E	64	848
013B	1 shift	(8 hrs	X	4 persons)	M	32	880
018B	2 shifts	(16 hrs	X	4 persons)	E	64	844
015B	1 shift	(8 hrs	X	4 persons)	M	32	976
016B	1 shift	(8 hrs	X	4 persons)	M	32	1,008
020B	2 shifts	(16 hrs	X	12 persons)	E	192	1,200
044B	10 shifts	(80 hrs	X	8 persons)	M	640	1,840
045B	10 shifts	(80 hrs	X	16 persons)	T	1,280	3,120
046B	6 shifts	(48 hrs	X	12 persons)	M/E	576	3,696
023B	4 shifts	(32 hrs	X	8 persons)	M	256	3,952
022B	3 shifts	(24 hrs	X	6 persons)	M	144	4,096
024B	3 shifts	(24 hrs	X	8 persons)	E	192	4,288
026B	3 shifts	(24 hrs	X	12 persons)	E	288	4,576
040B	4 shifts	(32 hrs	X	10 persons)	M	320	4,896
027B	2 shifts	(16 hrs	X	4 persons)	E	64	4,960
021B	2 shifts	(16 hrs	X	6 persons)	M	96	5,056
034B	4 shifts	(32 hrs	X	12 persons)	M	384	5,440
035B	3 shifts	(24 hrs	X	6 persons)	M	144	5,584
032B	1 shift	(8 hrs	X	8 persons)	M	64	5,648
033B	2 shifts	(16 hrs	X	8 persons)	M	128	5,776
029B	5 shifts	(40 hrs	X	8 persons)	E	320	6,096
030B	2 shifts	(16 hrs	X	8 persons)	E	128	6,224
025B	4 shifts	(32 hrs	X	12 persons)	E	384	6,608
031B	3 shifts	(24 hrs	X	8 persons)	M	192	6,800
038B	12 shifts	(96 hrs	X	16 persons)	M	1,536	8,336
039B	4 shifts	(32 hrs	X	6 persons)	R	192	8,528
036B	3 shifts	(24 hrs	X	12 persons)	M	288	8,816
037B	6 shifts	(48 hrs	X	12 persons)	M	576	9,392
115B	2 shifts	(16 hrs	X	4 persons)	E	64	9,456
041B	2 shifts	(16 hrs	X	4 persons)	R	224	9,680
042B	2 shifts	(16 hrs	X	16 persons)	E	256	9,936
043B	3 shifts	(24 hrs	X	16 persons)	E	384	10,320
114B	2 shifts	(16 hrs	X	10 persons)	E	160	10,480
301B	2 shifts	(16 hrs	X	5 persons)	M	80	10.560
047B	2 shifts	(16 hrs	X	30 persons)	M/E/R	480	11,040
053B	1 shift	(8 hrs	X	20 persons)	M/E	160	11,200
300B	1 shift	(8 hrs	X	2 persons)	R	16	11,216

Table 3-12. LRB Headcount - Vertical Assembly Building

VAB

OMI	SHIFTS	HOURS	TECHS	TYPE	TASK HOURS	TOTALS
048C	4	32	2	M	64	64
054C	3	24	6	M	48	112
151C	5	40	2	E	80	192
050C	4	32	2	M	64	256
049C	4	32	2	E	64	320
051C	5	40	2	M	80	400
150D	1	8	7	M	56	456
055D	3	24	14	M	336	792
250E	1	8	2	M	16	808
057D	2	16	4	E	64	872
065D	1	8	2	E	16	888
058D	2	16	2	E	32	920
064D	1	8	2	E	16	936
066D	1	8	2	M	16	952
056D	1	8	6	M	48	1000
067D	2	16	2	M	32	1032
155E	3	24	14	M	336	1368
060D	2	16	4	E	64	1432
059D	4	32	4	M	128	1560
157E	2	16	4	E	64	1624
165E	1	8	2	E	16	1640
158E	2	16	2	E	32	1672
164E	1	8	2	M	16	1688
166E	1	8	2	M	16	1704
156E	1	8	6	M	48	1752
167E	2	16	2	M	32	1784
160E	2	16	4	E	64	1848
159E	4	32	4	M	128	1976
061F	33	264	8	M/E	2112	4088
069F	3	24	2	M	48	4136
062F	1	8	6	E	48	4184
063F	3	24	4	E	96	4280
073F	3	24	14	M	256	4536
077F	4	32	20	E	640	5176
078F	1	8	20	M/E	160	5336

Table 3-13. LRB Headcount - Launch Pad

PAD

OMI	SHIFTS	HOURS	TECHS	TYPE	TASK HOURS	TOTAL
070G	2	16	4	M	64	64
071G	2	16	4	M	64	128
072G	7	84	16	M	1344	1472
079T	1	8	20	M	160	1632
074G	12	96	2	M	192	1824
080T	1	8	20	M/E	160	1632
075G	18	144	2	M	288	2272
081H	1	8	6	E	48	2320
076G	1	8	8	M	64	2384
084H	4	32	4	M	132	2516
350H	18	144	8	TPS	1152	3668
083H	1	8	2	M	16	3684
082H	1	8	2	M	16	3700
085H	7	56	3	M	168	3868
088H	1	8	6	E	48	3916
086H	3	24	6	M	144	4060
090H	4	32	6	M	192	4252
089H	1	8	4	M	32	4284
093H	1	8	4	E	32	4316
087H	6	48	4	E	192	4508
091H	1	8	6	M	48	4556
094H	3	24	4	M	96	4652
092H	2	16	6	E	96	4784
095H	5	40	6	M	240	4988
096H	1	8	4	M	32	5020
097H	1	8	6	M	48	5068
098I	3	24	30	M&E	720	5788
102H	4	32	8	R	256	6044
104H	3	24	4	M	96	6140
101H	4	32	3	M	96	6236
099H	5	40	4	M	160	6396
103H	2	16	4	E	64	6460
105H	3	24	2	E	48	6508
106H	4	32	6	M	192	6700
100H	6	48	6	E	288	6988
360H	6	48	8	R	384	7372
111H	3	24	4	M	96	7468
108H	2	16	2	M	32	7500
107H	1	8	4	M	32	7532
110H	2	16	2	E	32	7564
109H	2	16	8	M	128	7692
112H	3	24	4	E	96	7788
190I	8	64	30	MER	1920	9708

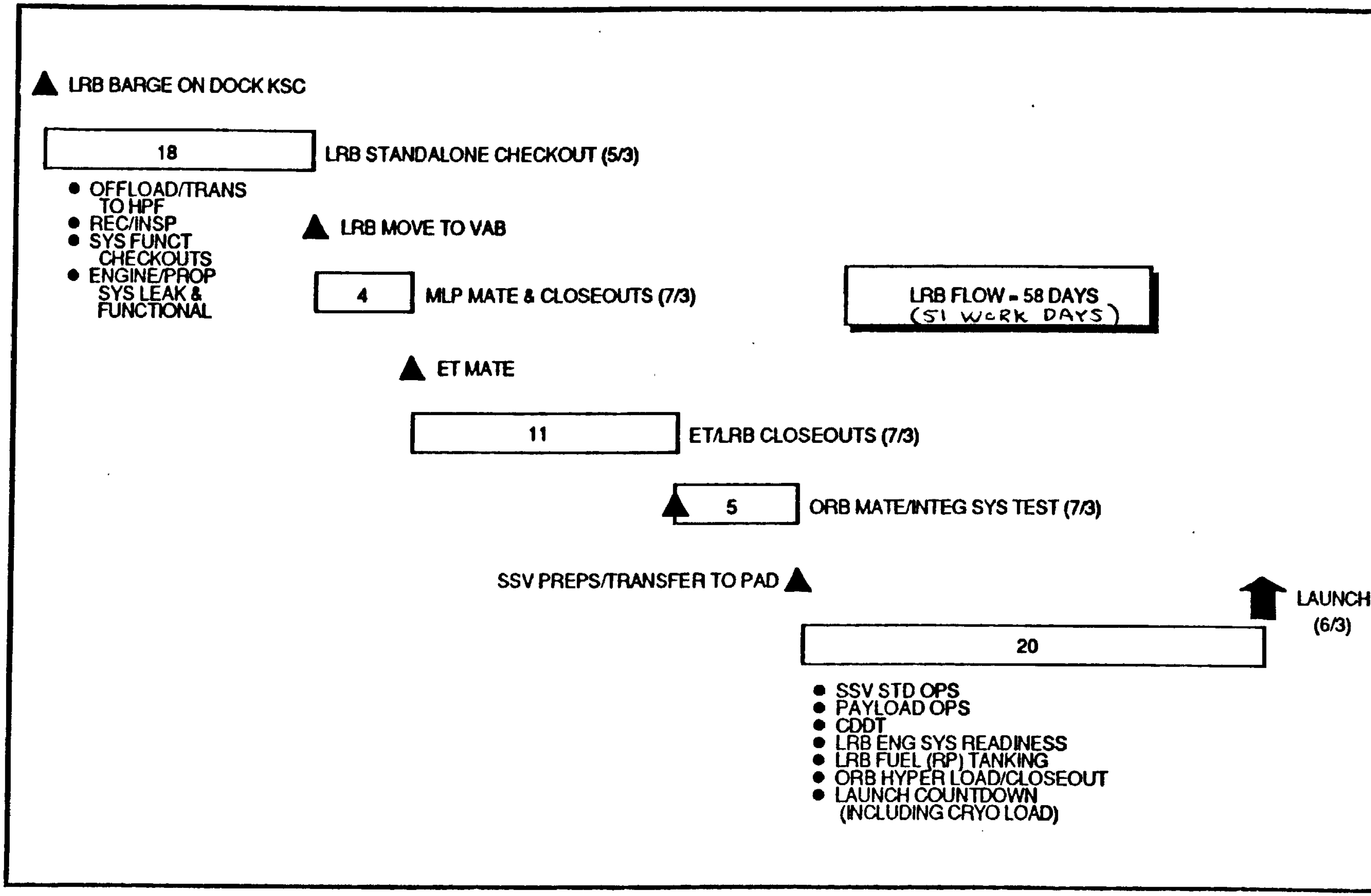

Figure 3-6. Generic LRB Process Flow

4.0 GENERIC CORE VEHICLE GROUND OPERATIONS (RECOVERABLE LO_2/LH_2 PROPULSION SYSTEMS)

This section presents the theoretical ground processing operations of the OEPSS generic core vehicle propulsion systems. The core vehicle concept herein uses a LO_2/LH_2 propulsion module that is recovered from near–orbital launch missions. Method and location of recovery are not specified. The generic propulsion systems are made equivalent to STS SSMEs in size, complexity, and ground processing requirements. The vehicle has no OMS/RCS, hypergolic, propellant tankage systems or processing requirements.

Data presented herein were extracted from a computerized shuttle OPF processing logic diagram under development by the Planning element of LSOC, the KSC shuttle processing contractor. At the time of use for this study it was not yet fully mature, but was advanced enough to provide the fundamental input to this section with a degree of credibility and accuracy not previously available.

The basic document is nine interconnected, computer–plotted, E–size drawings that show approximately 274 prime processing activities associated with a shuttle orbiter at the KSC OPF. About 110 of those items were identified as pertaining to the OEPSS generic core vehicle. Those items were extracted and reformatted for OEPSS while retaining the documented processing logic.

The OEPSS generic core vehicle top logic diagram is a reformatted extraction of that document showing the principal activities. System "trees" were then developed, WADs identified, and duration, headcount, and total manhours tabulated. Note that manhours are for "hands–on" skills <u>only</u> as defined in the skill mix data also included in this section. In general, the skill mix includes Process Engineers (system engineers), Operations (technicians), and SR&QA (inspectors). Supervision, administration, and the wide variety of support to those groups is not included. A summary skill mix for the SPC, circa October 1987, is presented in Section 1.4 of this report and can be used as desired.

4.1 ACRONYMS AND ABBREVIATIONS

APU	auxiliary power unit
CKS	checks
C/O	checkout
DPS	Data Processing System
ECS	Environmental Control System
F&B	fill and bleed
FLT	flight
FRT	flight readiness test
H_2O	water
He	helium

HGM	hot gas manifold
HYD	hydraulics
ISO	isolation (test)
L&F	leak and functional
LH_2	liquid hydrogen
LO_2	liquid oxygen
LPS	Launch Processing System (computerized)
MPS	Main Propulsion System
NH_3	ammonia
OPS	operations, also OPERS
ORB	orbiter
POI	post–operations instructions
POSU	pre–operations set–up
PRES	pressure
R&R	remove and replace
SIG	signature (test)
SRB	solid rocket booster
SSME	Space Shuttle Main Engine
SYS	system
VAB	Vehicle Assembly Building
TVC	thrust vector control
VJ	vacuum jacket
WBS	water spray boiler

4.2 TOP LOGIC DIAGRAM

The "top logic diagram" in Figure 4–1 shows the major processing tasks for the generic core vehicle utilizing a recoverable LH_2/LO_2 propulsion module requiring recovery and refurbishment. The diagram covers activities from receipt of the core at a processing facility, through rollout, to the total vehicle integration facility. The processing activities for the following systems are presented in Critical Path Method (CPM) format.

- Engines (LH_2/LO_2)
- Heat transfer/control (ammonia and water spray)
- Hydraulics (propulsion–related only)

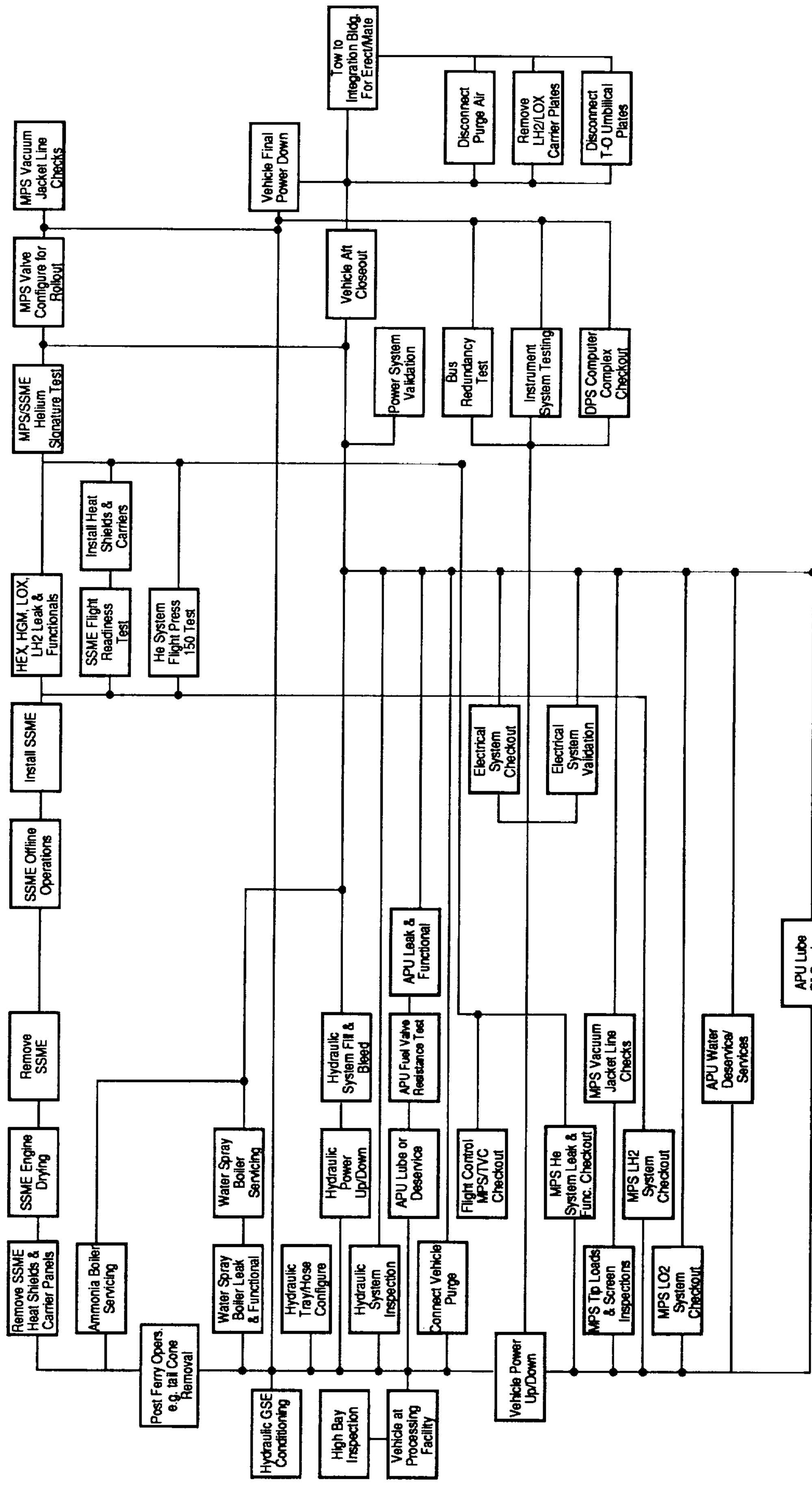

Figure 4–1. OEPSS Generic Core Vehicle Top Logic Diagram

- Auxiliary power unit (APU — hypergol driven)
- Purges
- Flight control (MPS/TVC)
- Electrical power
- Main propulsion system (MPS)
- Umbilicals

For each of the following systems, detailed logic diagrams and processing duration and manpower are shown as follows:

- Engine systems (Figure 4–2, Table 4–1)
- Main propulsion system (Figure 4–3, Table 4–2)
- Hydraulics and APU (Figures 4–4, Table 4–3)
- Electrical system (Figure 4–5, Table 4–4)
- Active thermal control system (Figure 4–6, Table 4–5)

The logic diagrams (Figures 4–2 through 4–6) show CPM–style task identity and performance flow, and Tables 4–1 through 4–5 list a tabulation of operation/OMI, task identity, duration, headcount, and total manhours.

The operation number (ORXXX) is an arbitrary identification number assigned by Planning elements to allow ease of tracking and scheduling in ARTEMIS and the Computer–Aided Planning and Scheduling System (CAPSS). It also allows flexibility in identifying tasks which encompass only a portion of an OMI (Operation and Maintenance Instruction). The VXXXX number shown at the bottom of most logic diagram boxes is the number for the OMI which provides specific operation task instruction.

These data provide designers insight into the chain of system–oriented procedures, the degree of parallel versus serial task possibilities, and the significant impact (often unsuspected) of pre– and post–operation setups which frequently double the prime scheduled accomplishment time.

Prime goal of these figures is to provide a moderately simple data base allowing designers to compare their systems, envisioned processing tasks, duration, and manpower, against the OEPSS generic vehicle systems data presented throughout this data book.

4.3 RESOURCE BY ACTIVITY

The Resource by Activity and the skill codes used by SPC (Table 4–6) are shown in Table 4–7 as a listing of detail processing tasks which show activity (skill code), WAD number (Work Authorization Document), activity description, activity duration (hours), and quantity (headcount).

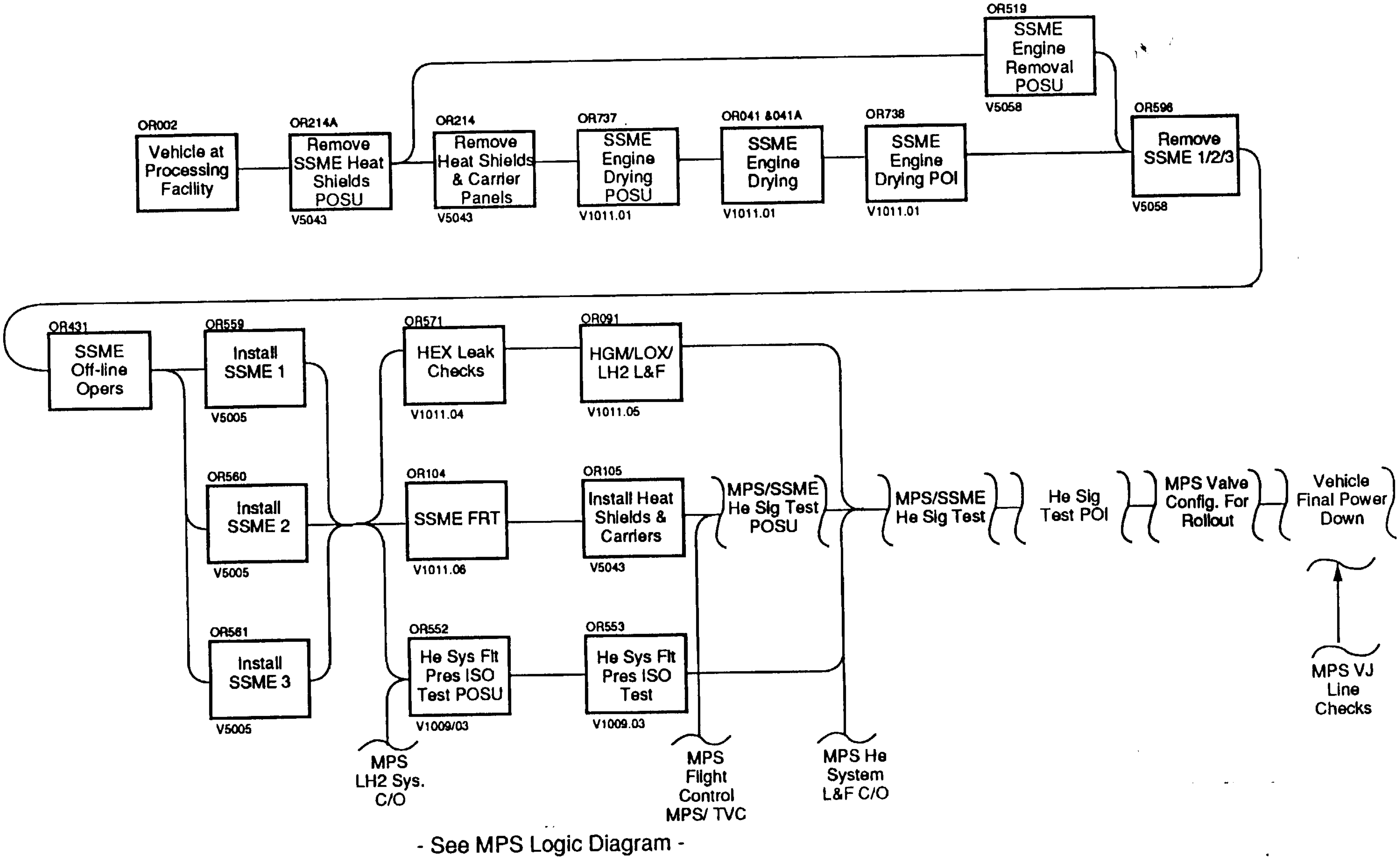

Figure 4–2. OEPSS Generic Core Vehicle Engine System Logic Diagram

Table 4–1. OEPSS Generic Core Vehicle Engine System Processing

Oper.	OMI	Activity	Dur. Hrs.	Head Count	Manhours
0R002	-	Vehicle at Processing Facility	-	-	
0R214A	V5043	Remove SSME heat shields & carriers POSU	9	12	108
0R214	V5043	Remove SSME heat shields & carriers	103	12	1236
0R737	V1011.01	SSME engine drying POSU	20	3	60
0R041/0.41A	V1011.01	SSME engine drying	24	7	168
0R738	V1011.01	SSME engine drying P0I	5	3	15
0R519	V5058	SSME engine removal POSU	64	14	896
0R596	V5058	Remove SSME 1/2/3	32	14	448
0R431	-	SSME offline opers	672	*18.7	12544
0R559	V5005	Install SSME1	12	15	180
0R560	V5005	Install SSME2	12	15	180
0R561	V5005	Install SSME3	12	15	180
0R571	V1011.04	Hex leak checks	50	3	150
0R091	V1011.05	HGM/LOX/LH2 L&F	54	4	216
0R104	V1011.06	SSME FRT	12	6	72
0R105	V5043	Install heat shields and carriers	72	10	720
0R552	V1009.03	He sys flt pres ISO test POSU	16	8	128
0R553	V1009.03	He sys flt pres ISO test	24	8	192
		TOTAL	1193		17,493

* Rocketdyne manpower for SSME offline O&M

	Techs	Quality	Engrs.
1st Shift	8	3	12
2nd Shift	8	3	2
3rd Shift	6	2	1
Shop support	6	3	2
	28	11	17

TOTAL - 56 Heads

672 Hrs. is 28 days of 3-shift operations for an average headcount of 18.7 at all times.

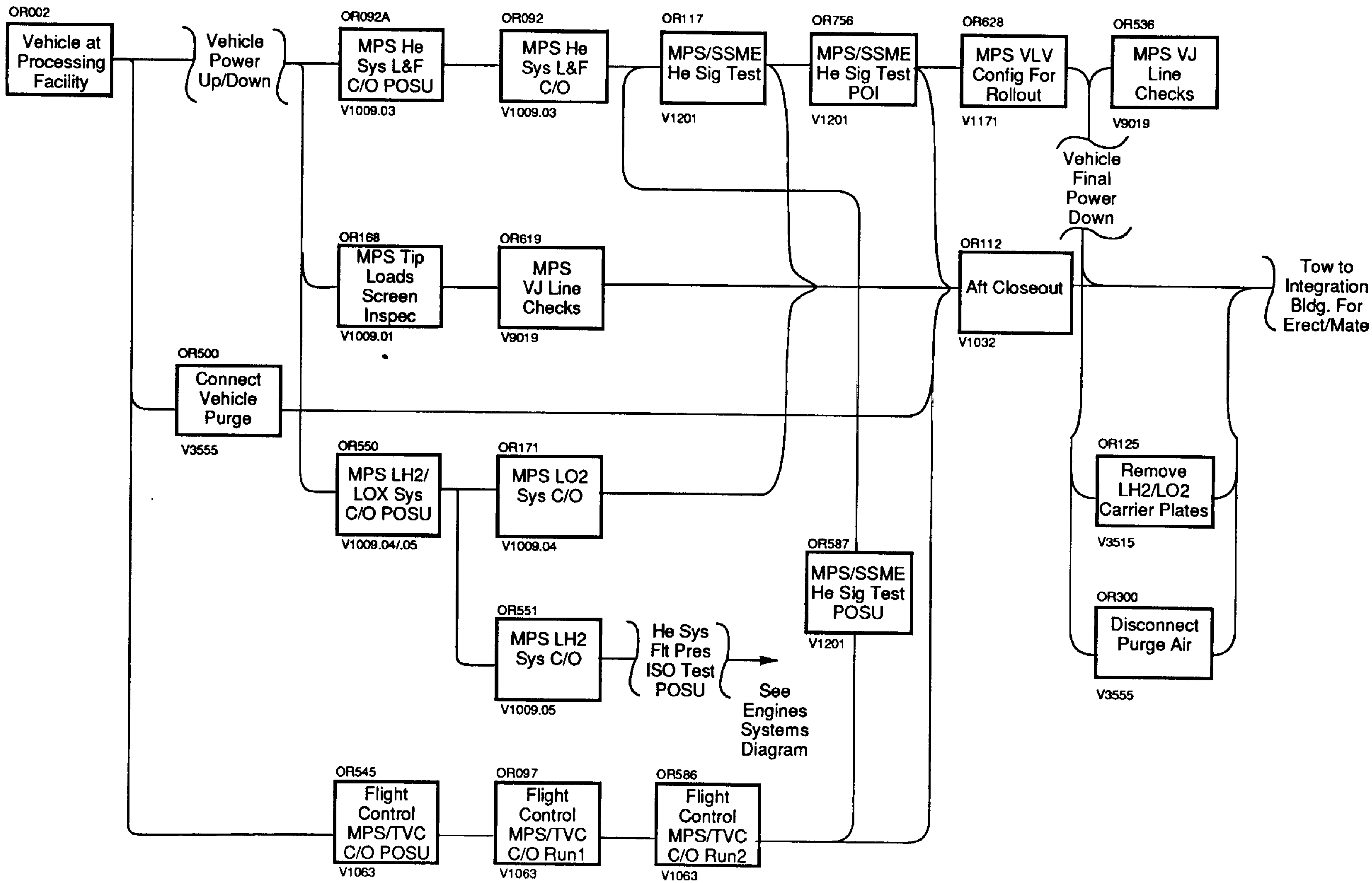

Figure 4–3. OEPSS Generic Core Vehicle MPS Logic Diagram

Table 4–2. OEPSS Generic Core Vehicle MPS Processing

Oper.	OMI	Activity	Dur. Hrs.	Head Count	Manhours
0R002	-	Vehicle at Processing Facility	-	-	
0R092A	V1009.03	MPS He sys. L&F C/O POSU	16	9	144
0R092	V1009.03	MPS He sys. L&F C/O	48	9	432
0R117	V1201	MPS/SSME He sig test	40	11	440
0R756	V1201	MPS/SSME He sig test POI	16	5	80
0R628	V1171	MPS VLV config. for rollout	4	2	8
0R536	V9019	MPS vacuum jacket line checks	8	5	40
0R168	V1009.01	MPS tip loads & screen inspect	56	9	504
0R619	V9019	MPS VJ line checks	8	5	40
0R112	V1032	Aft closeout *	312	15	4680
0R500	V3555	Connect vehicle purge	4	7	28
0R125	V3515	Remove LH2/LO2 carrier plates	4	3	12
0R550	V1009.04/.05	MPS LH2/LO2 Sys. C/O POSU	16	8	128
0R171	V1009.04	MPS LO2 sys. C/O	48	8	384
0R587	V1201	MPS/SSME He Sig test POSU	72	7	504
0R300	V3555	Disconnect purge air	4	7	28
0R551	V1009.05	MPS LH2 sys C/O	48	8	384
0R545	V1063	Flight control MPS/TVC C/O POSU	8	4	32
0R097	V1063	Flight control MPS/TVC C/O Run 1	10	4	40
0R586	V1063	Flight control MPS/TVC C/O Run 2	10	4	40
		TOTAL	732		7948

* Aft closeout includes the full spectrum of vehicle activities (not propulsion only)

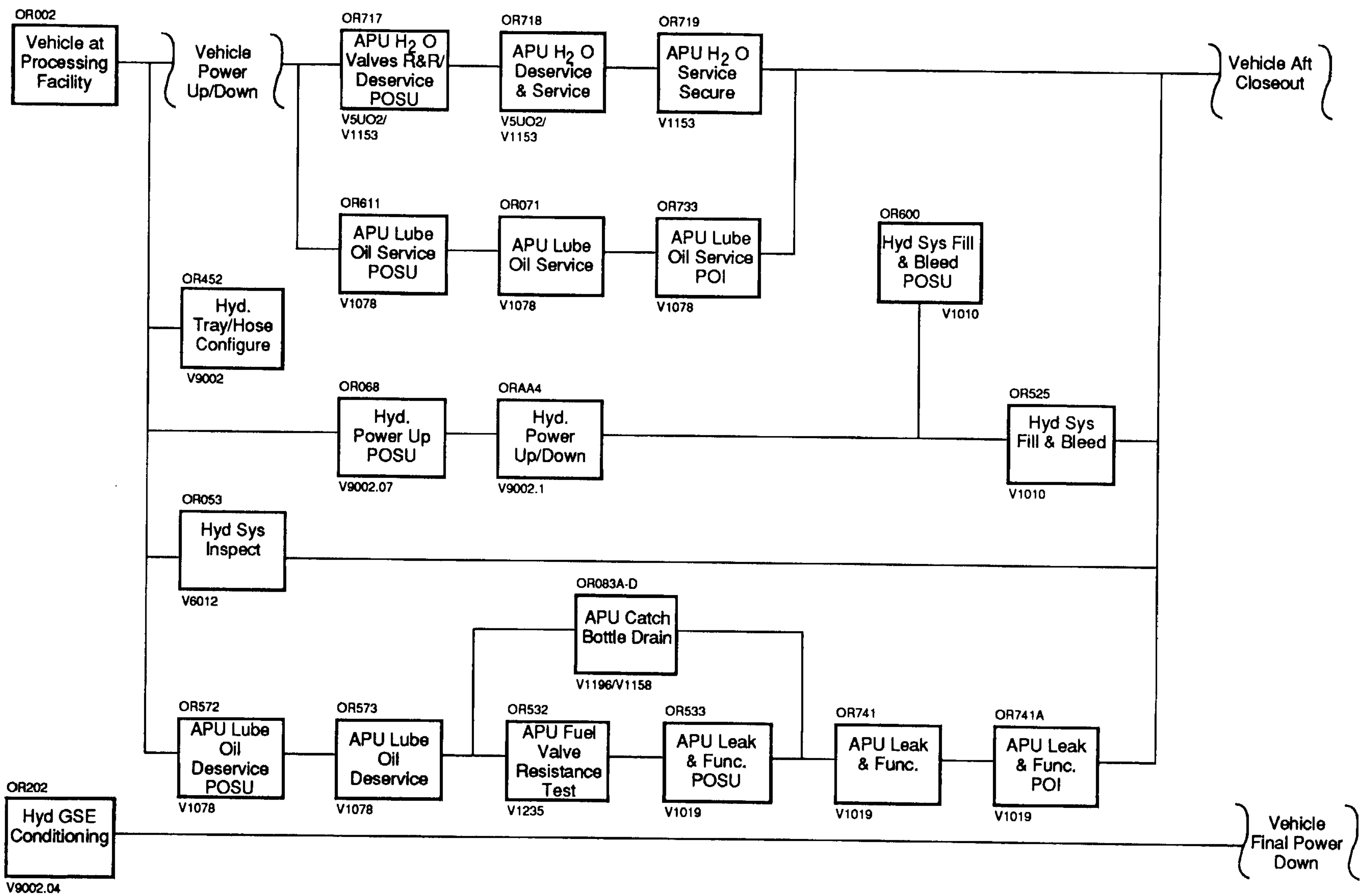

Figure 4–4. OEPSS Generic Core Vehicle Hydraulics and APU Logic Diagram

Table 4–3. OEPSS Generic Core Vehicle Hydraulics and APU Processing

Oper.	OMI	Activity	Dur. Hrs.	Head Count	Manhours
0R002	-	Vehicle at Processing Facility	-	-	
0R717	V5U02/V1153	APU H20 VLVS R&R/Deservice POSU	32	5	160
0R718	V5U02/V1153	APU H20 Deservice/Service	80	8	640
0R719	V1153	APU H20 Service secure	4	4	16
0R611	V1078	APU lube oil service POSU	8	5	40
0R071	V1078	APU lube oil service	26	10	260
0R733	V1078	APU lube oil service POI	8	4	32
0R600	V1010	Hyd. sys. fill & bleed POSU	24	5	120
0R452	V9002	Hyd. tray/hose configure	10	11	110
0R068	V9002.07	Hyd Power-up POSU	17	3	51
0RAA4	V9002.1	Hyd. Power-up/down	2	11	22
0R525	V1010	Hyd.sys. fill & bleed	32	14	448
0R053	V6012	Hyd. sys. inspect	64	4	256
0R083 A-D	V1196/1158	APU catch bottle drain	96	23	2208
0R572&A	V1078	APU lube/oil deservice POSU (STSX .67)*	64	10	640
0R573	V1078	APU lube/oil deservice	9	10	90
0R532	V1235	APU fuel vlv. resistance test	40	5	200
0R533	V1019	APU leak & functional POSU	16	10	160
0R741	V1019	APU leak & functional	176	10	1760
0R741A	V1019	APU leak & functional POI	48	8	384
		TOTAL	756		7597

* Contains POSU for 3 procedures; one of which is for OMS/RCS hypergols not used by generic core.

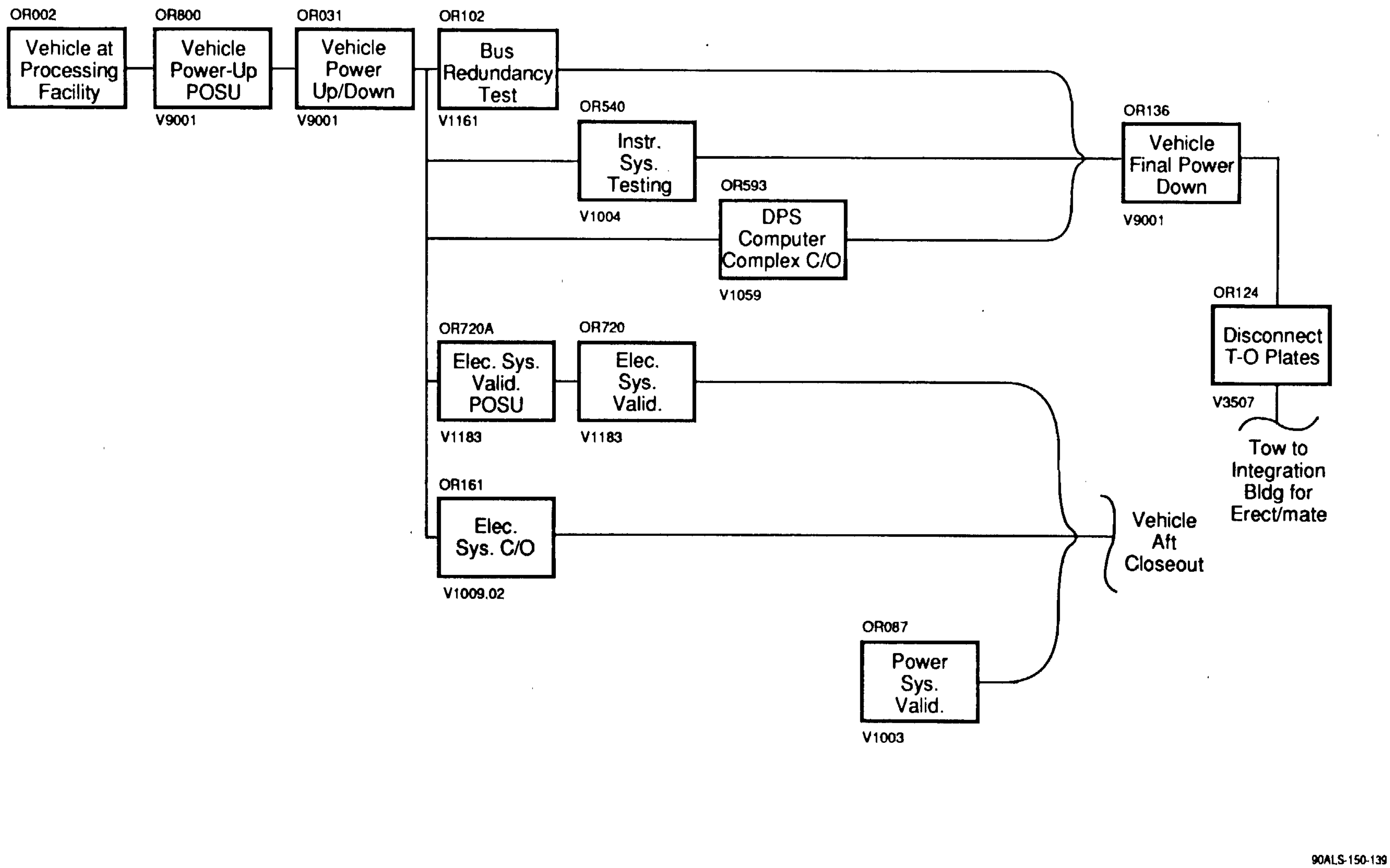

Figure 4–5. OEPSS Generic Core Vehicle Electrical System Logic Diagram

Table 4–4. OEPSS Generic Core Vehicle Electrical Systems Processing

Electrical Systems Processing Duration and Manpower

Oper.	OMI	Activity	Dur. Hrs.	Head Count	Manhours
0R002	-	Vehicle at Processing Facility	-	-	
0R800	V9001	Vehicle power-up POSU	26	14	364
0R031	V9001	Vehicle power-up/down	2	10	20
0R102	V1161	Bus redundancy test 128/15 x.5	64	8	512
0R540	V1004	Instrument system testing	48	5	240
0R593	V1059	DPS computer complex c/o	8	4	32
0R136	V9001	Vehicle final power down	2	8	16
0R124	V3507	Disconnect T-O umbilical plates	4	6	24
0R720A	V1183	Electrical system validation POSU	8	14	112
0R720	V1183	Electrical system validation	20	7	140
0R161	V1009.02	Electrical system C/O	44	8	352
0R087	V1003	Power system validation	48	11	528
		TOTAL	274		2340

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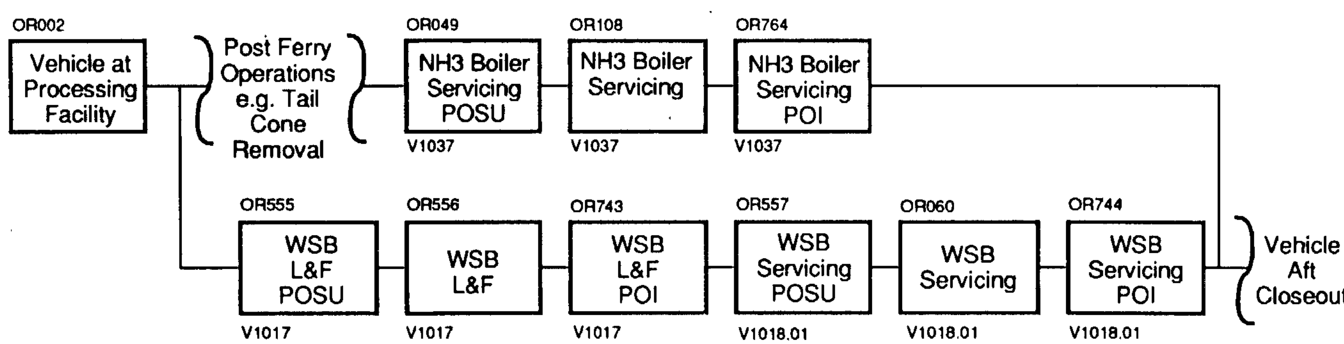

Figure 4–6. OEPSS Generic Core Vehicle Thermal Control System Logic Diagram

Table 4–5. OEPSS Generic Core Vehicle Thermal Control System Processing

Active Thermal Control System Processing Duration and Manpower

Oper.	OMI	Activity	Dur. Hrs.	Head Count	Manhours
0R002	-	Vehicle at Processing Facility	-	-	
0R049	V1037	Ammonia boiler servicing POSU	64	7	448
0R108	V1037	Ammonia boiler servicing	24	11	264
0R764	V1037	Ammonia boiler servicing POI	2	4	8
0R555	V1017	WSB leak and functional POSU	32	5	160
0R556	V1017	WSB leak and functional	144	8	1152
0R743	V1017	WSB leak and functional POI	4	4	16
0R567	V1018.01	WSB servicing POSU	8	7	56
0R060	V1018.01	WSB servicing	12	7	84
0R744	V1018.01	WSB servicing POI	2	4	8
		TOTAL	292		2196

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Table 4-6. OEPSS Generic Core Vehicle — Skill Codes

Code	Skill
LDT	Rocketdyne technicians (SSME)
LEE	LSOC/SPC engineer
LFS	LSOC safety operations
LOM	LSOC management operations
LOMMVDR	Move director
LOTGSEE	Technician, GSE, electrical
LOTGSEM	Technician, GSE, mechanical
LOTGSESP	Technician, GSE, sampling
LOTORBE	Technician, orbiter electrical
LOTORBM	Technician, orbiter, mechanical
LOTSCO	Technician, spacecraft operator
LNQI	Quality inspector, NASA
LQQI	Quality inspector, flight element
SSC	Support operations, crane crew
SSHRIG	Support operations, rigger
SSTHEQ	Support operations, heavy equipment

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The tabulation in Table 4-7 is presented in alphanumeric order of activity number, e.g., ORAA4, ORO18, etc. These numbers are arbitrarily assigned by SPC Planning elements to allow flexibility in tracking and computer manipulation for scheduling of tasks. This is especially valuable in managing numerous tasks which encompass only a portion of an OMI (Operation and Maintenance Instruction). Alpha-plus 4-digit numbers accompanying the activity number are OMI procedure numbers which contain specific task performance instructions, e.g., V9002.01, V3508, etc.

This resource sample data was derived during planning for the generic baseline. It is based on a success-oriented schedule and on historical data on task accomplishment. This data will enable designers to compare their systems, processing operations, headcount, and skill mix with those for the OEPSS generic vehicle.

4.4 PROCESSING CRITICAL PATH TASKS AND DURATION

The processing critical path has been extracted and developed from SPC logic diagram data which contains notation for "float time," i.e., the time frame in hours during which a task may be scheduled with the flexibility necessary to respond to anomalies and resources availability. A task

Table 4–7. Resource by Activity (Skill Mix) (Sheet 1 of 9)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
ORAA4	LFS LNQI LQQI LOTGSEM LOTORBM	V9002.01	Hydraulic Power Up/Down	2	1 1 1 3 5
ORO31	LEE LNQI LQQI LOTSCO LOTGSEE	V9001	Vehicle Power Up/Down	2	5 1 1 1 1
ORO41	LEE LNQI LQQI LOTORBM	V1011.01	SSME Engine Drying	15	2 1 2 2
ORO41A	LEE LNQI LQQI LOTORBM	V1011.01	SSME Engine Drying	9	2 1 2 2
ORO49	LEE LFS LQQI LOTGSEM LOTORBM	V1037	Ammonia Boiler Servicing	64	1 1 2 2 1
ORO53	LNQI LQQI	V6012	Vehicle Hydraulic System	64	2 2
ORO60	LEE LNQI LQQI LOTSCO LOTGSEM LOTORBM	V1018.01	WSB Servicing APU/Hyd Wtr Spray Boiler Servicing (LPS)	12	1 1 2 1 1 1
ORO68	LQQI LOTORBM	V9002.07	Hydr Power Up Walkdown/Veh Preps (Hyd Power-Up POSUs)	17	1 2
ORO71	LEE LFS LNQI LQQI LOTGSEM LOTORBE LOTORBM	V1078	APU Lube Oil Servicing (LPS)	26	1 1 1 2 2 1 2
ORO83A	LEE LFS LOM LQQI LOTGSEM LOTORBM	V1196	APU/Catch Bottle Drain	24	2 2 1 4 8 6

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Table 4-7. Resource by Activity (Skill Mix) (Sheet 2 of 9)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
ORO83B	LEE LFS LOM LQQI LOTGSEM LOTORBM	V1196	APU Catch Bottle Drain/He	32	2 2 1 4 8 6
ORO83C	LEE LFS LOM LQQI LOTGSEM LOTORBM	V1196	APU Catch Bottle Drain/He	24	2 2 1 4 8 6
ORO83D	LEE LFS LOM LQQI LOTGSEM LOTORBM	V1196	APU Catch Bottle Drain/He	16	2 2 1 4 8 6
ORO87	LEE LNQI LQQI LOTSCO LOTGSEE	V1003	Vehicle Power System Validation	48	1 1 3 3 3
ORO91	LEE LNQI LQQI	V1011.05	SSME HGM/LOX/LH_2 Sys Lk Cks (LPS)	54	2 1 1
ORO92	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.03	MPS Leak and Funct Test (LPS) (He System Checkout)	48	1 2 2 1 1 2
ORO92A	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.02	MPS He Sys Checkout POSU	16	1 2 2 1 1 2
ORO97	LEE LQQI	V1063	Flight Control MPS TVC C/O	10	3 1
OR102	LEE LQQI LOTSCO	V1161	Vehicle Bus Redundancy Test	128	12 2 1
OR104	LEE LQQI	V1011.06	SSME FRT	12	5 1

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Table 4-7. Resource by Activity (Skill Mix) (Sheet 3 of 9)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR105	LFS LNQI LQQI LOMMVDR LOTGSEM LOTORBM	V5043	Install SSME Heat Shield	72	1 1 1 1 1 5
OR108	LEE LNQI LQQI LOTSCO LOTGSEM LOTORBM	V1037	Ammonia Boiler Servicing, OP and De-serv (LPS)	24	2 1 2 1 3 2
OR112	LEE LNQI	V1032	Vehicle (AFT) Closeout Prior to Move to VAB	312	1 3
OR117	LEE LNQI LQQI LOTSCO SSHRIG LOTGSEM LOTORBM	V1201	MPS/SSME He Signature Test (OPF)	40	3 1 2 1 1 2 1
OR124	LQQI LOTGSEM LOTORBE LOTORBM	V3507	Orb Cabling Config C/L (Disconnect T-O Umb Cables)	4	1 2 2 1
OR125	LQQI LOTORBM	V3515	Remove LH_2/LO_2 Carrier PL	4	1 2
OR136	LEE LNQI LQQI LOTSCO	V9001	Vehicle Power Up/Power Down OPS Options (Orbiter Final Power Down)	2	5 1 1 1
OR161	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.02	MPS Leak and Funct Test (LPS)	44	1 1 2 1 1 2
OR168	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.01	MPF Tip-Loads/Screen and Flapper Seal Insp	56	2 1 2 1 1 2

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Table 4–7. Resource by Activity (Skill Mix) (Sheet 4 of 9)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR171	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.04	MPS Leak and Funct Test (LPS) (MPS LO_2 System Checkout)	48	1 1 2 1 1 2
OR201	LEE LFS	V5003	Tail Cone Removal Preps	34	1 1
OR211	LEE LFS SSC LNQI LQQI SSTHEQ LOMMVDR LOTORBE LOTORBM	V5003	Remove Tail Cone	8	1 1 4 1 1 4 1 1 5
OR214	LEE LFS LNQI LQQI LOMMVDR LOTGSEM LOTORBM	V5043	SSME Heat Shield Instl and Removal (Remove SSME Heat Shields and Carrier Panels)	103	1 1 1 2 1 1 5
OR214A	LEE LFS LNQI LQQI LOMMVDR LOTGSEM LOTORBM	V5043	Remove SSME Heat Shields (Cont.)	9	1 1 1 2 1 1 5
OR300	LQQI LOTGSEE LOTGSEM LOTORBM	V3555	Disconnect Orbiter Purge (OPF ECS)	4	1 2 2 2
OR452	LFS LNQI LQQI LOTGSEM LOTORBM	V9002	Vehicle Hyd Tray/Hose Reconfi	10	1 1 1 3 5
OR500	LQQI LOTGSEE LOTGSEM LOTORBM	V3555	Connect Vehicle Purge (OPF ECS)	4	1 2 2 2

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Table 4–7. Resource by Activity (Skill Mix) (Sheet 5 of 9)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR519	LDT LEE LFS LNQI LQQI LOTORBE LOTORBM	V5058	SSME Removal Horiz (POSUs)	64	7 1 1 1 1 1 2
OR525	LEE LQQI LOTGSEM LOTORBE LOTORBM	V1010	Hyd System Fill Bleed and C/O (LPS)	32	2 2 3 1 6
OR532	LEE LNQI LQQI LOTORBE	V1235	APU Fuel Valve Resistance Test	40	1 1 1 2
OR533	LEE LFS LNQI LQQI LOTSCO LOTGSEM LOTORBM	V1019	APU Leak and Functional Test (POSU)	16	1 1 1 2 1 2 2
OR536	LNQI LQQI LOTGSEM LOTORBM	V9019	MPS VJ Line Checks	8	1 1 2 1
OR540	LEE LQQI LOTORBE	V1004	Vehicle Instr Syst Testing (LPS)	48	1 2 2
OR545	LEE LQQI	V1063	Flight Control MPS TVC C/O and SRB Simulated	8	3 1
OR550	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.04	MPS Leak and Func Test (LPS) (LH_2/LO_2 System C/O POSU)	16	1 1 2 1 1 2
OR551	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.05	MPS Leak and Func Test (LH_2 System Checkout)	48	1 1 2 1 1 2

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Table 4-7. Resource by Activity (Skill Mix) (Sheet 6 of 9)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR552	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.03	MPS Leak and Func Test (LPS) (He System Flt Press ISO Test)	16	1 1 2 1 1 2
OR553	LEE LNQI LQQI LOTSCO LOTORBE LOTORBM	V1009.03	He Syst Flt Press ISO Test (LPS)	24	1 1 2 1 1 2
OR555	LQQI LOTGSEM LOTORBE	V1017	Hyd Wtr Spray Boiler L&F (LPS) (WSB Leak and Function POSU)	32	2 2 1
OR556	LEE LNQI LQQI LOTSCO LOTGSEM LOTORBE LOTORBM	V1017	Hyd Wtr Spray Boiler L&F (LPS) (WSB Leak and Funct)	144	1 1 2 1 1 1 1
OR557	LQQI LOTGSEM LOTORBM LOTGSESP	V1018.01	Hyd Wtr Spray Boiler L&F (LPS) (WSB Servicing POSUs)	8	2 2 2 1
OR559	LDT LEE LFS LNQI LQQI LOTORBE LOTORBM	V5005	SSME Installation (Install SSME 1)	12	7 1 1 1 2 1 2
OR560	LDT LEE LFS LNQI LQQI LOTORBE LOTORBM	V5005	SSME Installation (Install SSME 2)	12	7 1 1 1 2 1 2
OR561	LDT LEE LFS LNQI LQQI LOTORBE LOTORBM	V5005	SSME Installation (Install SSME 3)	12	7 1 1 1 2 1 2

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Table 4–7. Resource by Activity (Skill Mix) (Sheet 7 of 9)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR571	LEE LQQI	V1011.04	SSME HEX/GOX Sys Leak Checks (LPS)	50	2 1
OR572	LEE LNQI LQQI LOTGSEM LOTORBE LOTORBM		POSUs (APU Lube Oil Servicing V1078/ APU Postflight V1196)	64	1 1 2 2 2 2
OR573	LEE LNQI LQQI LOTGSEM LOTORBE LOTORBM	V1078	APU Lube Oil Deservice (LPS)	9	1 1 2 2 2 2
OR586	LEE LQQI	V1063	Flight Control MPS TVC C/O and SRB Simulated	10	3 1
OR587	LQQI LOTSCO SSHRIG LOTGSEM LOTORBM	V1201	MPS/SSEM He Sig Test (POSU)	72	2 1 1 2 1
OR593	LEE LQQI LOTSCO	V1059	DPS Comp Compelx C/O (LPS)	8	1 2 1
OR596	LDT LEE LFS LNQI LQQI	V5058	SSME Removal (Horiz) (Remove SSME 1/2/3)	32	7 1 1 1 1
OR600	LQQI LOTGSEM LOTORBM	V1010	Hyd Syst Fill and Bleed (POSU)	24	1 3 1
OR611	LQQI LOTGSEM LOTORBM	V1078	APU Lube Oil Service (POSU)	8	2 2 1
OR619	LNQI LQQI LOTGSEM LOTORBM	V9019	MPS VJ Line Checks	8	1 1 2 1
OR628	LEE LQQI	V1171	MPS Valve Config for Roll	4	1 1
OR717	LQQI LOTGSEM LOTORBM	V1153/ V5U02	APU Water Deservice/Water	32	2 2 1

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Table 4–7. Resource by Activity (Skill Mix) (Sheet 8 of 9)

OPF34: OPF Processing STS–34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR718	LEE LQQI LOTGSEM LOTORBE LOTORBM	V1153/ V5U02	APU Water Deservice/Water	80	1 2 2 1 2
OR719	LQQI LOTGSEM LOTORBM	V1153	APU Water Deservicing (Secure)	4	1 2 1
OR720	LEE LQQI LOTSCO LOTGSEE	V1183	Vehicle Elect Syst Validation	20	1 2 1 3
OR720A	LEE LQQI LOTGSEE LOTORBE	V1183	Vehicle Electrical System Val	8	1 2 3 7
OR733	LQQI LOTGSEM LOTORBM	V1078	APU Lube Oil Service (POSU)	8	1 2 1
OR737	LQQI LOTORBM	V1011.01	SSME Eng Drying (POSU)	20	1 2
OR738	LQQI LOTORBM	V1011.01	SSME Eng Drying (POI)	5	1 2
OR741	LEE LFS LNQI LQQI LOTSCO LOTGSEM LOTORBM	V1019VL2	APU Leak and Functional	176	1 1 1 2 1 2 2
OR741A	LEE LFS LQQI LOTGSEM LOTORBM	V1019VL2	APU Leak and Functional (PCI)	48	1 1 2 2 2
OR743	LQQI LOTGSEM LOTORBE	V1017	WSB Leak and Funct (POI)	4	1 2 1
OR744	LQQI LOTGSEM LOTORBM	V1018.01	WSB Servicing (POI)	2	1 2 1
OR756	LQQI LOTGSEM LOTORBM	V1201	He Signature Test (POI)	16	2 2 1

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Table 4–7. Resource by Activity (Skill Mix) (Sheet 9 of 9)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR764	LQQI LOTGSEM LOTORBM	V1037	Ammonia Boiler Servicing	2	1 2 1
OR800	LNQI LQQI LOTGSEE LOTGSEM LOTORBE LOTORBM	V9001	Vehicle Power Up POSUs	26	2 3 3 2 2 2

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having zero hours of float time is a "critical path" task and a direct contributor to the minimum scheduled processing timeline. It will appear as a series event in a schedule barchart.

In Table 4–8 the critical path tasks are presented approximately in the order of scheduled accomplishment. The OR number is an activity designator arbitrarily assigned by SPC Planning elements to allow ease in tracking and computer manipulation of tasks, many of which encompass only portions of Operation and Maintenance Instructions (OMIs). Scheduled durations are totaled to assist designers in assessing impact of these critical path tasks.

Design attention to critical path items, and their elimination, simplification or time reduction, is a prime potential source of life cycle cost reduction manifested by reduced processing time, reduced headcount, less facilities and GSE, and (perhaps more important) increased launch rate. The net effect is a potential for dramatic reduction in cost to deliver payload ($/lb) to orbit.

Table 4-8. OEPSS Generic Core Vehicle Thermal Process Critical Path

Activity		Duration, hrs.
0R002	Vehicle at Processing Facility door	-
0R214	Remove SSME heat shields and carriers	103
0R737	SSME engine drying POSU	20
0R041	SSME engine drying	24
0R738	SSME engine drying POI	5
0R596	Remove SSME (20 hr/engine) x 3	90
0R431	SSME offline operations 672 hrs	-
0R559	Install SSME (12 hr/engine) x 3	36
0R571	SSME HEX leak checks	50
0R091	SSME HGM/LOX/LH2 leak and functional	54
0R105	Install SSME heat shield and carrier	72
0R587	MPS/SSME He signature test (preps)	72
0R117	He signature test	40
0R756	He signature test POI	16
0R112	Vehicle aft closeout	312
	TOTAL	894

1. 894 hrs equates to 111.7 shifts
2. LSOC planning for STS-33 shows
   57 days process time for these tasks;
   an average 2.1 shifts per day, 7 days per week.

91ALS-031-18

5.0 GENERIC ORBIT VEHICLE GROUND OPERATIONS – RECOVERABLE STAGE WITH HYPERGOLIC PROPULSION SYSTEMS

This section presents the theoretical ground processing operations of OEPSS generic orbit vehicle propulsion systems. The orbit vehicle concept herein uses hypergolic propellants and returns from low earth orbit launch missions. Method and location of recovery are not specified. Propulsion systems are made equivalent to STS OMS/RCS/FRCS in size, complexity, and ground processing requirements. The vehicle has no LO_2/LH_2, hydraulics, water spray boiler, or APU systems. It does have fuel cell, power reactant storage and distribution (PRSD), and ammonia boiler, and it provides electrical power to the generic core during flight.

Data presented herein were extracted from a computerized shuttle OPF processing logic diagram under development by the Planning element of LSOC, the KSC shuttle processing contractor. At the time of use for this study it was not yet fully mature, but was advanced enough to provide the fundamental input to this section with a degree of credibility and accuracy not previously available. The basic document is nine interconnected, computer–plotted, E–size drawings showing approximately 274 prime processing activities associated with a shuttle orbit vehicle at the KSC OPF. About 54 of these items were identified as pertaining to the OEPSS generic orbit vehicle. These items were extracted and reformatted for OEPSS while retaining the documented processing logic.

The OEPSS generic orbit vehicle top logic diagram is a reformatted extract of the shuttle logic diagrams showing principal activities. System "trees" were then developed, WADs identified, and duration, headcount, and total manhours tabulated. Note that manhours are for "hands on" skills only as defined in the skill mix data also included in this section. In general, the skill mix includes Process Engineers (system engineers), Operations (technicians), and SR&QA (inspectors). Supervision, administration, and the wide variety of support to those groups is not included.

5.1 ACRONYMS AND ABBREVIATIONS

CKS	checks
C/O	checkout
DPS	Data Processing System
ECS	Environmental Control System
F/C	fuel cell
FLT	flight
FRCS	Forward Reaction Control System
FRT	flight readiness test
FUNC	functional
I/F	interface
L&F	leak and functional (test)

LPS	Launch Processing System (computerized)
NH_3	ammonia
OMS	Orbital Maneuvering System
OPS	operations, also OPERS
ORB	orbiter
POIO	post–operations instructions
POSU	pre–operations set–up
PRSD	Power Reactant Storage and Distribution System
RCS	Reaction Control System
SYS	system
VAB	Vehicle Assembly Building
VLV	valve
WSB	water spray boiler

5.2 TOP LOGIC DIAGRAM

The following "top logic diagram," Figure 5–1, shows the major processing tasks for the generic orbit vehicle which is a recoverable hypergolic propulsion module which requires recovery and refurbishment. The diagram covers activities from receipt of the orbit vehicle at a processing facility, through rollout, to the total vehicle integration facility.

Processing activities for the following systems are shown in critical path method (CPM) format, allowing ready assessment of task flow and hierarchy:

- OMS pods
- FRCS
- Heat transfer control (ammonia)
- Fuel cells
- Purges
- Flight control
- Electrical power
- PRSD
- Umbilicals

Reusable Vehicle - Hypergolic Propulsion

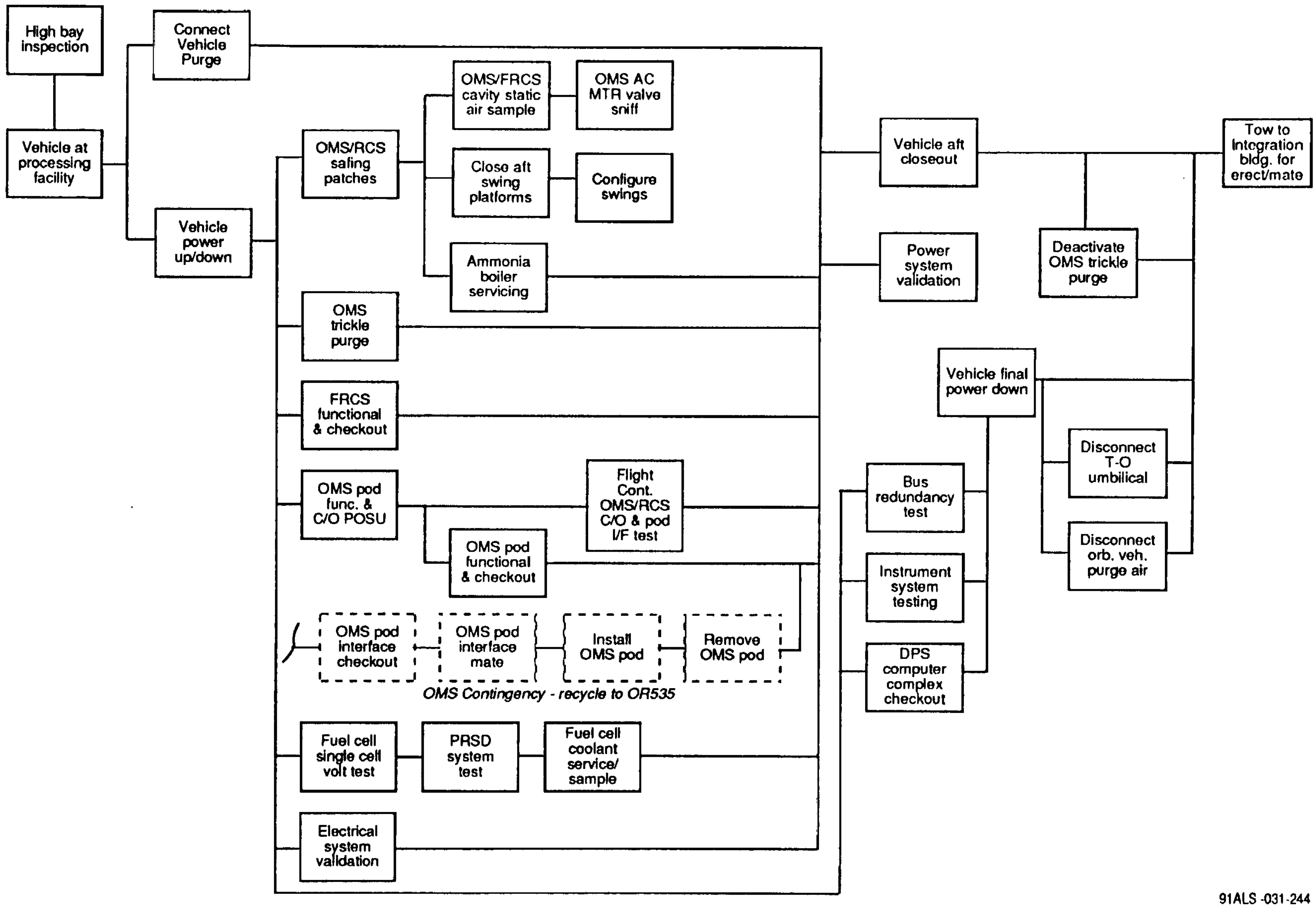

Figure 5–1. OEPSS Generic Orbit Vehicle Top Logic Diagram

These systems are treated in the logic diagrams for the Propulsion System, Electrical System, and Active Thermal Control System shown in Figures 5–2, 5–3, and 5–4, respectively. The logic diagrams show CPM–style task identity and performance flow. The tabulation of operation/OMI, task identity, duration, headcount, and total manhours are also shown for these systems in Tables 5–1, 5–2, and 5–3, respectively.

The operation number (ORXXX) is an arbitrary identification assigned by Planning elements to allow ease of tracking and scheduling in ARTEMIS and the Computer–Aided Planning and Scheduling System (CAPSS). It also allows flexibility in identifying tasks which encompass only a portion of an OMI (Operation and Maintenance Instruction). The VXXXX number shown at the bottom of most logic diagram boxes is the number for the OMI which provides specific operation task instruction.

The above data will provide designers insight into the chain of system–oriented procedures, the degree of parallel versus serial task possibilities, and the significant impact (often unsuspected) of pre– and postoperation setups which frequently double the primary scheduled accomplishment time.

Prime goal of these figures is to provide a moderately simple data base allowing designers to compare their systems, processing tasks, duration, and manpower against the OEPSS generic vehicle systems data presented in this databook.

5.3 RESOURCE BY ACTIVITY

The Resource by Activity and the skill codes used by SPC (Table 5–4) shown in Table 5–5 as a listing of detail processing tasks which show activity (skill code), WAD number (Work Authorization Document), activity description, activity duration (hours), and quantity (headcount).

The tabulation in Table 5–5 is presented in alphanumeric order of activity number, e.g., OR018, OR031, etc. These numbers are arbitrarily assigned by SPC Planning elements to allow flexibility in tracking and computer manipulation for scheduling of tasks. This is especially valuable in managing numerous tasks which encompass only a portion of a OMI (Operation and Maintenance Instruction). Alpha–plus 4–digit numbers accompanying the activity number are OMI procedure numbers which contain specific task performance instructions, e.g., V3508, V9001, etc.

This resource sample data was derived during planning for mission STS–34 and represents generic, success–oriented scheduling based on historical data on task accomplishment.

5.4 PROCESSING CRITICAL PATH TASKS AND DURATION

The following processing critical paths have been extracted and developed from SPC logic diagram data which contain notation for "float time," i.e., the time frame in hours during which a task may be scheduled with the flexibility necessary to respond to anomalies and resource availability. A task having zero hours of float time is a "critical path" task and a direct contributor to the minimum scheduled processing timeline. It will appear as a series event in a schedule barchart.

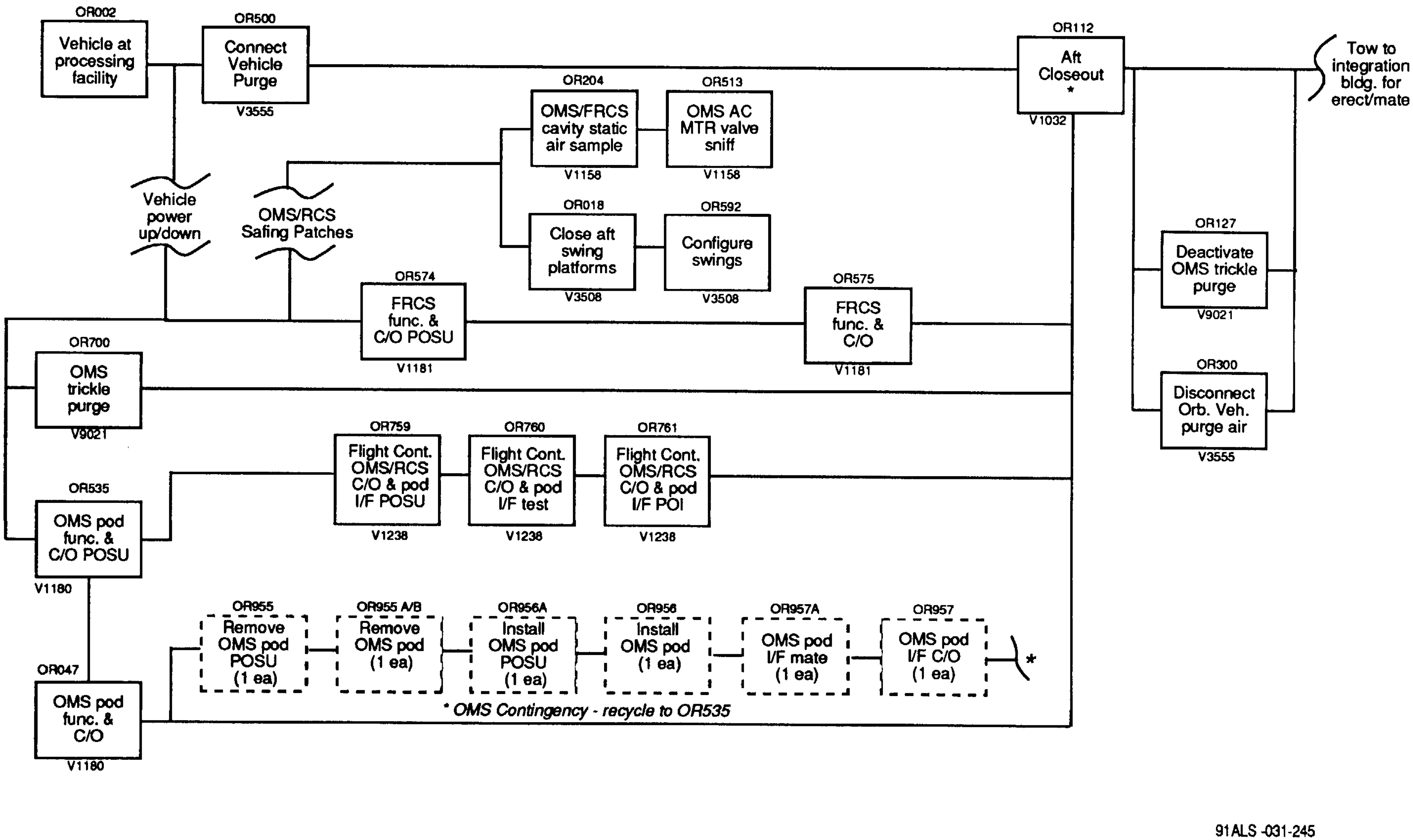

Figure 5–2. OEPSS Generic Orbit Vehicle Propulsion System Logic Diagram

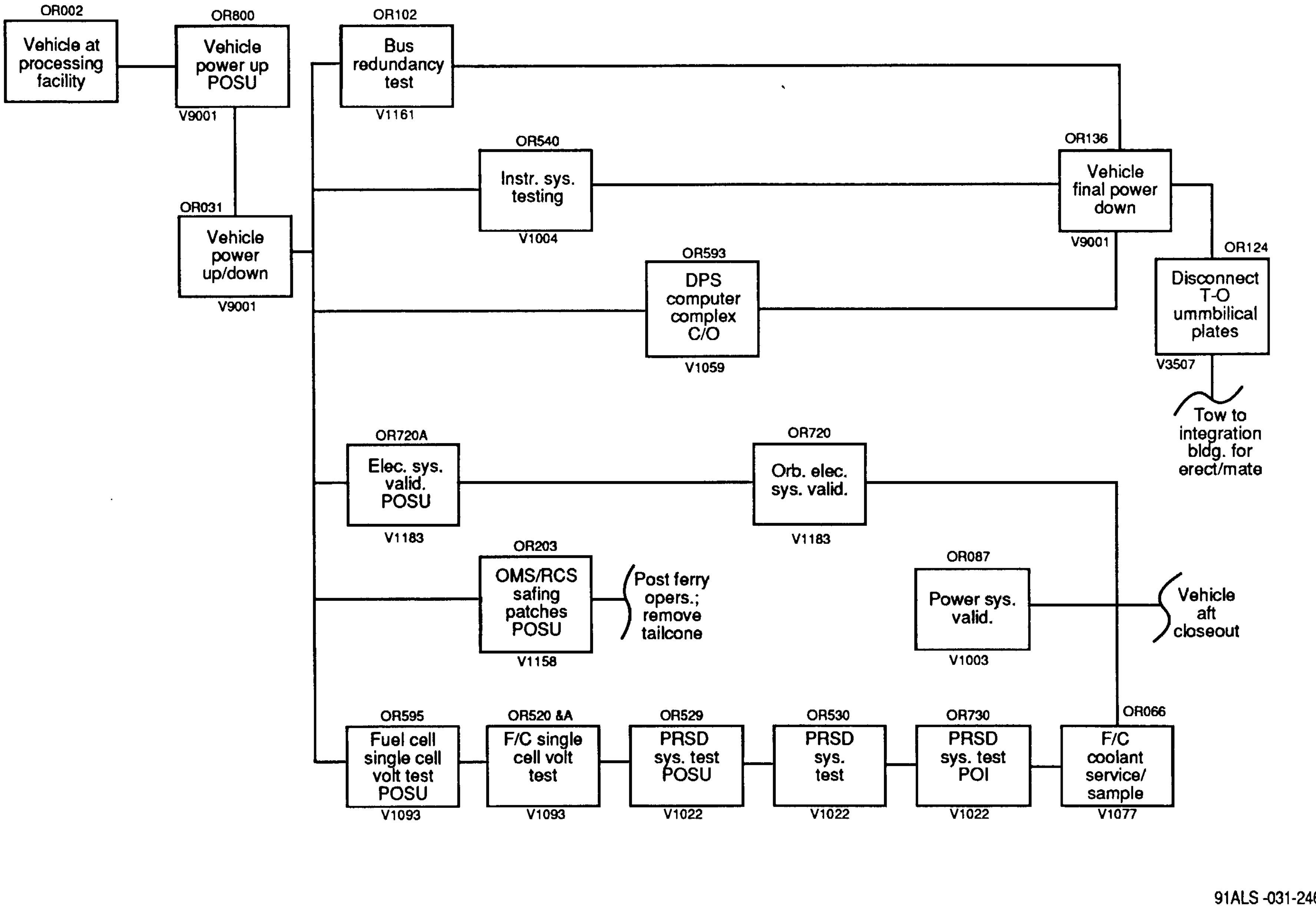

Figure 5-3. OEPSS Generic Orbit Vehicle Electrical System Logic Diagram

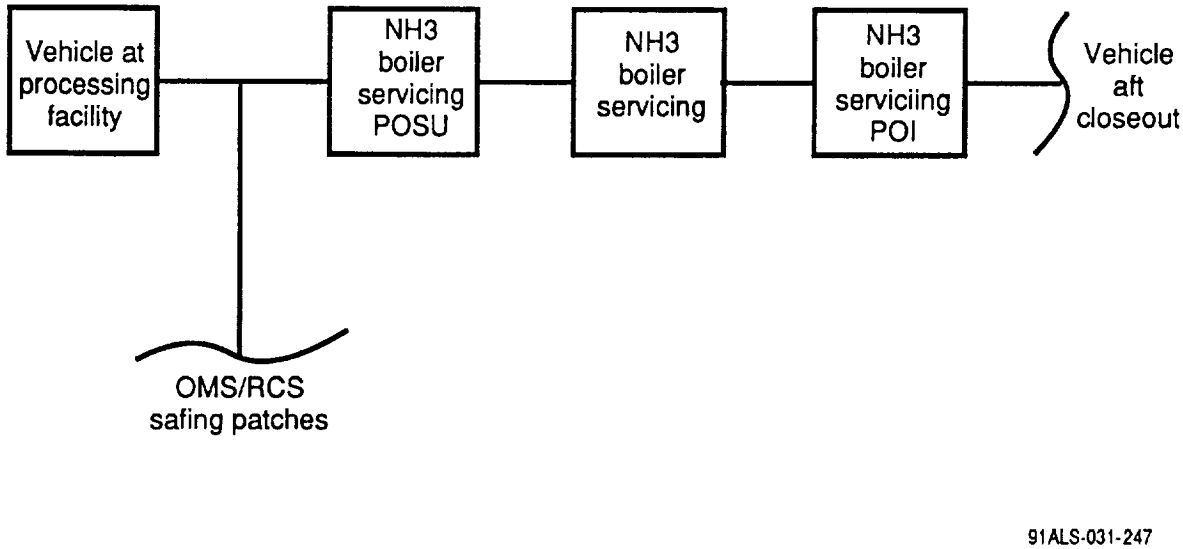

Figure 5-4. OEPSS Generic Orbit Vehicle Active Thermal Control System Logic Diagram

Table 5-1. OEPSS Generic Orbit Vehicle Propulsion Systems Processing Duration and Manpower

Operation Number	OMI	Activity	Duration (h)	Headcount	Manhours
OR002	-	Vehicle at processing facility	-	-	-
OR112	V1032	Aft closeout*	312	15	4,680
OR500	V3555	Connect vehicle purge	4	7	28
OR204	V1158	OMS/FRCS cavity static air sample	37	23	851
OR513	V1158	OMS ac mtr valve shift	48	4	192
OR574	V1181	FRCS functional and checkout POSU	32	9	288
OR575	V1181	FRCS functional and checkout	56	9	504
OR127	V9021	Deactivate OMS trickle purge	4	5	20
OR300	V3555	Disconnect vehicle purge air	4	7	28
OR700	V9021	OMS trickle purge	5	3	15
OR535	V1180	OMS POD functional and checkout POSU	24	10	240
OR759	V1238	Flight controls OMS/RCS C/O and POD I/F POSU	2	3	6
OR760	V1238	Flight controls OMS/RCS C/O and POD I/F Test	6	5	30
OR761	V1238	Flight controls OMS/RCS C/O and POD I/F POI	2	3	6
OR047	V1180	OMS POD functional and C/O	168	10	1,680
OR955	V5011	Remove OMS POD POSU (1 ea.)	(8)	19	(152)
OR955 A&B	V5011	Remove OMS POD (1 ea.)	(16)	19	(304)
OR956A	V5011	Install OMS POD (1 ea.)	(24)	19	(456)
OR957	V1225	OMS POD interface checkout (1 ea.)	(64)	8	(512)
OR957	V1226	OMS POD interface mate (1 ea.)	(48)	8	(384)
-	V5008	FRCS module removal POSU	(8)	13	(104)
-	V5008	FRCS module removal	(8)	13	(104)
-	V5008	FRCS module reinstallation	(8)	13	(104)
-	V5008	FRCS module installation POI	(8)	13	(104)
Total			704		8,558**

Notes: 1. OMS POD and FRCS module R&R are shown as contingency operations and not included in total manhours.**

2. OMS and/or FRCS R&R require recycle to OR535 and/or OR574, respectively, with consequent additional duration and manhours.

* Aft closeout includes full spectrum of vehicle systems in addition to "propulsion systems."

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Table 5-2. OEPSS Generic Orbit Vehicle Electrical Systems Processing Duration and Manpower

Operation Number	OMI	Activity	Duration (h)	Headcount	Manhours
OR002	-	Vehicle at processing facility	-	-	-
OR800	V9001	Vehicle power-up POSU	26	14	364
OR102	V1161	Orb. bus redundancy test (STSX.5)	128	8	1,024
OR031	V9001	Vehicle power-up/down	2	10	20
OR540	V1004	Instrument system testing	48	5	240
OR136	V9001	Vehicle final power down	2	8	16
OR593	V1059	DPS computer complex checkout	8	4	32
OR124	V3507	Disconnect T-O umbilical plates	4	6	24
OR720A	V1183	Electrical system validation POSU	8	13	104
OR720	V1183	Vehicle electrical system validation	20	7	140
OR203	V1158	OMS/RCS safing patches POSU	4	4	16
OR087	V1003	Orb. power system validation	48	11	528
OR595	V1093	Fuel cell single cell volt test POSU	40	6	240
OR520 and A	V1093	Fuel cell single cell volt test	24	10	240
OR529	V1022	PRSD system test POSU	24	8	192
OR530	V1022	PRSD system test	180	14	2,520
OR730	V1022	PRSD system test POI	10	5	50
OR066	V1077	Fuel cell coolant service/sample	8	5	40
Total			584		5,790

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Table 5-3. OEPSS Generic Orbit Vehicle Active Thermal Control System Processing Duration and Manpower

Operation Number	OMI	Activity	Duration (h)	Headcount	Manhours
OR002	-	Vehicle at processing facility	-	-	-
OR049	V1037	Ammonia boiler servicing POSU	64	7	448
OR108	V1037	Ammonia boiler servicing	24	11	264
OR764	V1037	Ammonia boiler servicing POI	2	4	8
Total			90		720

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Table 5-4. OEPSS Generic Orbit Vehicle – Skill Codes

Code	Skill
LDT	Rocketdyne technicians (SSME)
LEE	LSOC/SPC engineer
LFS	LSOC safety operations
LOM	LSOC management operations
LOMMVDR	Move director
LOTGSEE	Technician, GSE, electrical
LOTGSEM	Technician, GSE, mechanical
LOTGSESP	Technician, GSE, sampling
LOTORBE	Technician, orbiter electrical
LOTORBM	Technician, orbiter, mechanical
LOTSCO	Technician, spacecraft operator
LNQI	Quality inspector, NASA
LQQI	Quality inspector, flight element
SSC	Support operations, crane crew
SSHRIG	Support operations, rigger
SSTHEQ	Support operations, heavy equipment

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Table 5-5. Resource by Activity (Skill Mix) (Sheet 1 of 4)

OPF34: **OPF Processing STS-34**
Type: **Develop Network**

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR031	LEE LNQI LQQI LOTSCO LOTGSEE	V9001	Orbiter Power Up/Down	2	5 1 1 1 1
OR031	LOTGSEM	V9001	Orbiter Power Up/Down	2	1
OR047	LEE LNQI LQQI LOTGSEM LOTORBE LOTORBM	V1180	OMS POD Functional and C/O	168	2 1 2 2 1 2
OR049	LEE LFS LQQI LOTGSEM LOTORBM	V1037	Ammonia Boiler Servicing	64	1 1 2 2 1
OR066	LEE LNQI LQQI LOTORBM LOTGSESP	V1077	ORB Fuel Cell Coolant Service (LPS)	8	1 1 1 1 1
OR087	LEE LNQI LQQI LOTSCO LOTGSEE	V1003	ORB Power System Validation	48	1 1 3 3 3
OR102	LEE LQQI LOTSCO	V1161	ORB Bus Redundancy Test	128	12 2 1
OR108	LEE LNQI LQQI LOTSCO LOTGSEM LOTORBM	V1037	Ammonia Boiler Servicing, Op and De-serv (LPS)	24	2 1 2 1 3 2
OR112	LEE LNQI LQQI LOTORBE LOTORBM	V1032 V1032	ORB (Aft) Closeout Prior to Move to VAB ORB (Aft) Closeout)	312 312	1 3 3 2 6
OR124	LQQI LOTGSEM LOTORBE LOTORBM	V3507	Disconnect T-O Umb Cables	4	1 2 2 1

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Table 5-5. Resource by Activity (Skill Mix) (Sheet 2 of 4)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR127	LQQI LOTGSEM LOTORBM	V9021	Deactivate OMS Trickle PU	4	2 2 1
OR136	LEE LNQI LQQI LOTSCO	V9001	OBR Power Up/Power Down DPS Options (LPS)	2	5 1 1 1
OR203	LEE LNQI LQQI LOTORBE	V1158	OMS/RCS OPF Deservicing Proc (LPS) (POSU 28 OMS/RCS Safing PA)	4	1 1 1 1
OR204	LEE LFS LOM LQQI LOTGSEM LOTORBM	V1158	(POSU 9 OMS/FRCS Cavity ST)	37	2 2 1 4 8 6
OR300	LQQI LOTGSEE LOTGSEM LOTORBM	V3555	Disconnect Orbiter Purge (OPF ECS)	4	1 2 2 2
OR500	LQQI LOTGSEE LOTGSEM LOTORBM	V3555	Connect Vehicle Purge	4	1 2 2 2
OR513	LEE LNQI LQQI LOTORBE	V1158	OMS/RCS OPF Deservicing Proc OMS AC Motor Valve Sniff (LPS)	48	1 1 1 1
OR520	LEE LFS LNQI LQQI LOTGSEM LOTORBE LOTORBM	V1093	F/C Single Cell Volt Test	16	1 2 1 2 1 1 2
OR520A	LEE LFS LNQI LQQI LOTGSEM LOTORBE LOTORBM		F/C Single Cell Volt Test	8	1 2 1 2 1 1 2

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Table 5-5. Resource by Activity (Skill Mix) (Sheet 3 of 4)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR529	LNQI LQQI LOTSCO LOTGSEM LOTORBM	V1022	Fuel Cell and PRSD System Test (POSU) (LPS)	24	1 2 1 3 4
OR530	LEE LNQI LQQI LOTSCO SSHRIG LOTGSEM LOTORBM	V1022	PRSD System Test	180	2 1 2 1 1 3 4
OR535	LEE LNQI LQQI LOTGSEM LOTORBE LOTORBM	V1180	OMS POD Functional and C/O (LPS)	24	2 1 2 2 1 2
OR540	LEE LQQI LOTORBE	V1004	ORB Instr Syst Testing (LPS)	48	1 2 2
OR574	LFS LQQI LOTGSEM LOTORBE LOTORBM	V1181	FRCS Functional and C/O (Module) POS	32	1 2 2 2 2
OR575	LEE LFS LQQI LOTGSEM LOTORBE LOTORBM	V1181	FRCS Functional and C/O	56	1 1 2 1 2 2
OR593	LEE LQQI LOTSCO	V1059	DPS Comp Complex C/O (LPS)	8	1 2 1
OR595	LQQI LOTORBE LOTORBM	V1093	F/C Single Cell Volt Test (LPS)	40	2 3 1
OR700	LNQI LQQI LOTORBM	V9021	OMS Trickle Purge	5	1 1 1
OR720	LEE LQQI LOTSCO LOTGSEE	V1183	ORB Electrical System Validation	20	1 2 1 3

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Table 5-5. Resource by Activity (Skill Mix) (Sheet 4 of 4)

OPF34: OPF Processing STS-34
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
OR720A	LEE LQQI LOTGSEE LOTORBE	V1183	ORB Electrical System Validation	8	1 2 3 7
OR730	LQQI LOTGSEM	V1022	PRSD System Test POI	10	2 3
OR759	LQQI LOTORBM	V1238	FLT Controls OMS/RCS C/O	2	1 2
OR760	LEE LQQI LOTORBM	V1238	FLT Controls OMS/RCS C/O	6	1 2 2
OR761	LQQI LOTORBM	V1238	FLT Controls OMS/RCS C/O	2	1 2
OR764	LQQI LOTGSEM LOTORBM	V1037	Ammonia Boiler Servicing	2	1 2 1
OR800	LNQI LQQI LOTGSEE LOTGSEM LOTORBE LOTORBM	V9001	Orbiter Power Up POSUs	26	2 3 3 2 2 2

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The critical path tasks for the generic OEPSS orbit vehicle and propulsion, electrical, and active thermal control systems are shown in Tables 5-6 through 5-9, respectively.

The critical path tasks are presented approximately in the order of scheduled accomplishment. The OR number is an activity designator arbitrarily assigned by SPC Planning elements to allow ease in tracking and computer manipulation of tasks, many of which encompass only portions of Operation and Maintenance Instructions (OMI). Scheduled durations are totalled to assist designers in assessing impact of these critical path tasks.

Design attention to critical path items, and their elimination, simplification or time reduction, is a prime potential source of life cycle cost reduction manifested by reduced processing time, reduced headcount, less facilities and GSE, and (perhaps more important) increased launch rate. The net effect is a potential for dramatic reduction in cost to deliver payload ($/lb) to orbit.

Table 5-6. OEPSS Generic Orbit Vehicle Ground Processing Overall Critical Path Tasks and Duration

Operation Number	Activity	Duration (h)
OR002	Vehicle at processing facility	–
OR800	Vehicle power-up POSU	26
OR031	Vehicle power up/down	2
OR595	Fuel cell single cell volt test POSU	40
OR520	Fuel cell single cell volt test	24
OR529	PRSD system test POSU	24
OR530	PRSD system test	180
OR730	PRSD system test POI	10
OR066	Fuel cell coolant service/sample	8
OR112	Vehicle aft closeout	312
–	Ready for tow to integration building for erect/mate	
Total		626

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Table 5-7. OEPSS Generic Orbit Vehicle Ground Processing Propulsion Systems Critical Path

Operation Number	Activity	Duration (h)
OR002	Vehicle at processing facility	-
OR535	OMS POD Functional and C/O POSU	24
OR047	OMS POD Functional and C/O	168
OR112	Aft closeout	112
-	Tow to integration building for erect/mate	-
Total		304

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Table 5-8. OEPSS Generic Orbit Vehicle Ground Processing Electrical Systems Critical Path

Operation Number	Activity	Duration (h)
OR002	Vehicle at processing facility	-
OR800	Vehicle power-up POSU	26
OR031	Vehicle power-up/down	2
OR595	Fuel cell single cell volt test POSU	40
OR520	Fuel cell single cell volt test	24
OR529	PRSD system test POSU	24
OR530	PRSD system test	180
OR730	PRSD system test POI	10
OR066	Fuel cell coolant service/sample	8
-	Vehicle aft closeout	-
Total		314

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Table 5-9. OEPSS Generic Orbit Vehicle Ground Processing Active Thermal Control Systems Critical Path

Operation Number	OMI	Activity	Duration (h)
OR002		Vehicle at Processing Facility	-
OR049		Ammonia boiler servicing POSU	64
OR108		Ammonia boiler servicing	24
OR764		Ammonia boiler servicing POI	2
-		Vehicle aft closeout	-
Total			90

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6.0 GENERIC CORE TANK GROUND OPERATIONS

This section presents ground processing operations of the generic core vehicle propellant tankage assembly. The assembly consists of the expendable LO_2/LH_2 tankage and components required to provide propellant during launch of the recoverable core vehicle. Mission of the core tank is comparable to that of the STS external tank (ET). The following ground processing logic diagrams and tasks data have been developed from the related Computer–Aided Planning and Scheduling System (CAPSS) under development by LSOC, the Shuttle processing contractor.

Supplementary data presented herein were extracted from CAPSS tabulations. Headcount and skill code data are probably accurate to +0 and -25% as task analysis reveals many supplementary support activities that have evolved in the field without comprehensive feedback to Planning elements. Further, these data represent historically–derived, success–oriented planning that cannot compensate for the infinite variety of problems and delays normally encountered in this very complex process. However, these data still represent the most concise and credible data base for these operations presently in existence.

6.1 ACRONYMS AND ABBREVIATIONS

C/O	checkout
DISC	disconnect
GUCP	ground umbilical carrier plate
He	helium
I/T	intertank
INJ	injection
LH_2	liquid hydrogen
LOX	liquid oxygen
LSOC	Lockheed Space Operations Co.
OPNS	operations
ORD	ordnance
POI	post–operations instruction
POSU	pre–operations set–up
REC	receive
RSS	Range Safety System
V/V	vent valve
WAD	Work Authorization Document

6.2 LOGIC DIAGRAM

Figure 6–1 is a Critical Path Method (CPM) logic diagram showing the prime tasks performance sequence for the generic core tank ground processing. Processing starts at the upper left–hand corner with Activity designator TE0001, "start of operations," and continues to the lower right–hand corner with Activity TE0032, "completion of operations (start of erect and mate)." Numbers at the top center of most task boxes are Work Authorization Document (WAD) numbers of the procedure (Operation and Maintenance Instruction) providing specific task instructions. These activity designators are arbitrarily assigned by Planning elements for tracking and computer manipulation during flow planning. They are especially useful in managing numerous tasks which encompass only part of an OMI.

The number at the top right–hand corner of each task box is the planned duration in hours for that task. Critical path total activity hours are noted in the bottom right–hand key. This duration represents the minimum expected duration of the entire process if no processing anomalies or unscheduled delays are encountered, i.e., a success–oriented schedule based on historical average expected performance. Letters at the beginning and end of each process chain are continuation designators noting tie points of the diagram.

This diagram is intended to provide designers with a simplified view of stage processing tasks to allow comparison with potential new designs, thereby aiding the iterative task of ultimate design simplification, decreased processing time, headcount and facilities, and, perhaps more important, increased launch rate.

6.3 PROCESSING ACTIVITIES, DURATION AND MANPOWER

Table 6–1 is a listing of the tasks in Figure 6–1, showing the additional elements of headcount and manhours. A few nonpropulsion tasks of interest to designers are included for reference, but not included in manhour data.

6.4 RESOURCE BY ACTIVITY

The Resource by Activity shown in Table 6–2 is a listing of detail processing tasks which show activity (skill code), WAD number (Work Authorization Document), activity description, activity duration (hours), and quantity (headcount). The skill codes are those used by the SPC and are shown in Table 6–3.

The tabulation in Table 6–2 is presented in alphanumeric order of Activity number, e.g., TE0002, TE0003, etc. These numbers are arbitrarily assigned by SPC Planning elements to allow flexibility in tracking and computer manipulation for scheduling of tasks. This is especially valuable in managing numerous tasks which encompass only a portion of an OMI (Operation and Maintenance Instruction). Alpha–plus 4–digit numbers accompanying the Activity number are OMI procedure numbers which contain specific task performance instructions, e.g., T5149, T5148, etc.

Table 6–1. Generic Core Tank Processing Activities, Duration and Manpower

Operation Number	OMI	Activity	Duration (h)	Headcount	Manhours
TE0001	–	Start operations	–	–	–
TE0002	T5149	Tank offload and secure	8	12	96
TE0003	T5149	Post operations	8	7	56
TE0004	T5148	Platform operations	8	5	40
TE0005	T6149	Receive inspection	40	7	280
TE0006	T1102/03	Preps for checkout	20	4	80
TE0007	T5048	Install intertank access kit	16	7	112
TE0008	T1109	LOX/LH_2 leak checks	16	4	64
TE0009	T1147	(Hazard) GUCP installation	8	5	40
TE0010	T1147	GUCP installation	24	4	96
TE0011	T5141	AFT hard point checkout	40	5	200
TE0012	T5153	Install range safety system eqpt	(8)	(4)	–
TE0013	T5142	Ordnance installation POSU	(8)	(5)	–
TE0014	T5142	(Hazard) ordnance installation	(8)	(5)	–
TE0015	T5142	Ordnance installation POI	(8)	(5)	–
TE0016	T5136	Leak port closeout	8	4	32
TE0018	T5238	Helium injection box C/O	16	4	64
TE0019	T1160	All systems test POSU	32	5	160
TE0020	T1160	(Hazard) all systems test	8	5	40
TE0021	T1160	All systems test POI	8	5	40
TE0022	T1101	Relief valve checks	8	4	32
TE0023	T1101	(Hazard) vent valve timing checks	8	4	32
TE0024	T1108	LH_2/LO_2 17 inch disconnect/meas/adj	48	4	192
TE0025	T5048	Remove intertank access kit	16	7	112
TE0026	T6248	Inspect/pre-move	16	4	64
TE0027	T5148	Platform operations	8	6	48
TE0028	T1102/03	Press/sense line disconnect	8	3	24
TE0029	T1145	Purge barrier seal installation	8	4	32
TE0030	T1101	LH_2/LO_2 vent disconnect	4	3	12
TE0031	T1104	Ancillary leak flow checks	8	4	32
TE0032	–	Operations complete — ready to start S0003, erect and mate	–	–	–
Total			392		1,980

Note: Operations in parenthesis ( ) not within OEPSS study scope; data not included in totals.

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Table 6–2. Resource by Activity (Skill Mix) (Sheet 1 of 2)

LModel: Generic Core Tank Ground Processing
Type: Generic Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
TE0002	LMQ LNQ LMTT	T5149	Tank Offload and Secure	8	2 2 8
TE0003	LMQ LNQ LMTT	T5149	Post Operations	8	2 1 4
TE0004	LMQ LMTT	T5148	Platform Operations	8	1 4
TE0005	LMQ LNQ LMTT	T6149	Rec Insp	40	2 1 4
TE0006	LMQ LNQ LMTT	T1102/03	Preps for Checkout	20	1 1 2
TE0007	LMQ LNQ LMTT	T5048	Instl I/T Access Kit	16	1 1 5
TE0008	LMQ LNQ LMTT	T1109	LOX/LH_2 Leak Checks	16	1 1 2
TE0009	LMQ LNQ LMTT	T1147	(Hazard) GUCP Instl	8	1 1 3
TE0010	LMQ LNQ LMTT	T1147	GUCP Instl	24	1 1 2
TE0011	LMQ LNQ LMTT	T5141	Aft Hard Point C/O	40	1 1 3
TE0012	LMQ LNQ LMTT	T5153	Instl RSS Equip	8	1 1 2
TE0013	LMQ LNQ LMTT	T5142	ORD Instl PCSU	8	1 1 3
TE0014	LMQ LNQ LMTT	T5142	ORD Instl (Hazard)	8	1 1 3
TE0015	LMQ LNQ LMTT	T5142	ORD Instl POI	8	1 1 3
TE0016	LMQ LNQ LMTT	T5136	Leak Port Closeout	8	1 1 2

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Table 6-2. Resource by Activity (Skill Mix) (Sheet 2 of 2)

LModel: Generic Core Tank Ground Processing
Type: Generic Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
TE0018	LMQ LNQ LMTT	T5238	He Inj Box C/O	16	1 1 2
TE0019	LMQ LNQ LMTT	T1160	All Systems Test POSU	32	2 1 2
TE0020	LMQ LNQ LMTT	T1160	All Systems Test (Hazard)	8	2 1 2
TE0021	LMQ LNQ LMTT	T1160	All Systems Test POI	8	2 1 2
TE0022	LMQ LNQ LMTT	T1101	Relief Valve Checks	8	1 1 2
TE0023	LMQ LNQ LMTT	T1101	(Hazard) V/V Timing Checks	8	1 1 2
TE0024	LMQ LNQ LMTT	T1108	LH_2/LO_2 17 in Disc/Meas/Adj	48	1 1 2
TE0025	LMQ LNQ LMTT	T5048	Rem I/T Access Kit	16	1 1 5
TE0026	LMQ LNQ LMTT	T6248	Insp/Pre-Move	16	1 1 2
TE0027	LMQ LNQ LMTT	T5148	Platform Operations	8	1 1 4
TE0028	LMQ LMTT	T1102/03	Press/Sense Line Disc	8	1 2
TE0029	LMQ LNQ LMTT	T1145	Purge Barrier Seal Instl	8	2 1 1
TE0030	LMQ LNQ LMTT	T1101	LH_2/LO_2 Vent Disc	4	1 1 1
TE0031	LMQ LNQ LMTT	T1104	Ancillary Leak Flow Checks	8	1 1 2
TE0032			Complete Operations (Start 50003, Erect and Mate)		–

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Table 6–3. Generic Core Tank Ground Processing – Skill Codes

Code	Skill
LMQ	Quality
LMTT	Tank technician
LNQ	NASA quality

This resource sample data was derived during planning for the generic baseline and is a success–oriented schedule based on historical data of task accomplishments.

6.5 PROCESSING CRITICAL PATH TASKS AND DURATION

A processing critical path has been extracted and developed from SPC Logic Diagram data which contains notation for "float time," i.e., the time frame in hours during which a task may be scheduled with the flexibility necessary to respond to anomalies and resource availability. A task having zero hours of float time is a "critical path" task and a direct contributor to the minimum scheduled processing timeline. It will appear as a series event in a schedule barchart.

The critical path tasks in Table 6–4 are presented approximately in the order of scheduled accomplishment. The TE number is an activity designator arbitrarily assigned by SPC Planning elements to allow ease in tracking and computer manipulation of tasks; many of which encompass only portions of Operation and Maintenance Instructions (OMIs). Scheduled durations are totalled to assist designers in assessing impact of these critical path tasks.

Design attention to critical path items and their elimination, simplification, or time reduction is a prime potential source of life cycle cost reduction manifested by reduced processing time, reduced headcount, less facilities and GSE, and (perhaps more important) increased launch rate. The net effect espoused by this study is a potential for dramatic reduction in cost to deliver payload ($/lb) to orbit.

Table 6-4. Generic Core Tank Ground Processing Critical Path Tasks and Duration

Operation Number	Activity	Duration (h)
TE0001	Start operations	-
TE0002	Offload and secure	8
TE0003	Post operations	8
TE0007	Install intertank access kit	16
TE0011	Aft hard point checkout	40
TE0012	Install range safety system eqpt	8
TE0016	Leak port closeout	8
TE0017	Leak port closeout (24-h wait)	24
TE0018	Helium injector box checkout	16
TE0019	All systems test POSU	32
TE0020	All systems test (hazard)	8
TE0021	All systems test POI	8
TE0026	Inspect/pre-move	16
TE0027	Platform operations	8
TE0024	LH_2/LO_2 17-inch disconnect/meas/adj	48
TE0032	Complete opers (start S0003, erect and mate)	-
Total		248

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7.0 GENERIC CORE PROPULSION STACKING

The generic core propulsion is the LO_2/LH_2 system recovered and reprocessed for launch in OPF–type operation. This section outlines the transfer from the processing facility to the VAB–type vehicle assembly/integration facility. Primary operations involve attachment of lifting harness, lift, mate, umbilical connections, and holddown post (HDP) activities. It is assumed that the core stage supports itself and the payload on thrust butts and holddown posts are autonomous from the booster HDPs.

Activities and WADs are modelled from lift and mate processes of an STS, SRB aft segment/ nozzle/skirt/TVC assembly. There are numerous theoretical similarities with a liquid propulsion core element, and the model is presented herein as a credible first approximation for the generic vehicle.

7.1 ACRONYMS AND ABBREVIATIONS

CONN	connect
DISC	disconnect
ELECT	electrical
HDP	holddown post
MECH	mechanical
UMB	umbilical
VAB	Vehicle Assembly Building
WAD	Work Authorization Document

7.2 LOGIC DIAGRAM

Figure 7–1 is a Critical Path Method (CPM) logic diagram showing the prime tasks performance sequence for the generic core propulsion stacking. Processing starts at the upper left–hand corner with Activity designator BLAB00 "core propulsion (transfer) to VAB," and continues to the bottom center with "ready for tank mate." Numbers at the top center of most task boxes are Work Authorization Document (WAD) numbers of the procedure (Operation and Maintenance Instruction) providing specific task instructions. These activity designators are arbitrarily assigned by Planning elements for tracking and computer manipulation during flow planning. They are especially useful in managing numerous tasks which encompass only part of an OMI.

The number at the top right–hand corner of each task box is the planned duration in hours for that task. Critical path total activity hours are noted in the bottom right–hand key. This duration represents the minimum expected duration of the entire process if no processing anomalies or unscheduled delays are encountered, i.e., a success–oriented schedule based on historical average expected performance. Letters at the beginning and end of each process chain are continuation designators noting tie points of the diagram.

This diagram is intended to provide designers with a simplified view of stage processing tasks to allow comparison with potential new designs, thereby aiding the iterative task of ultimate design simplification, decreased processing time, headcount and facilities, and, perhaps more important, increased launch rate.

7.3 PROCESSING ACTIVITIES, DURATION AND MANPOWER

Table 7–1 is a listing of the tasks in Figure 7–1 showing the additional element of headcount and manhours.

7.4 RESOURCE BY ACTIVITY

The Resource by Activity shown in Table 7–2 is a listing of detail processing tasks which show activity (skill code), WAD number (Work Authorization Document), activity description, activity duration (hours), and quantity (headcount). The skill codes are those used by the SPC and are shown in Table 7–3.

The tabulation in Table 7–2 is presented in alphanumeric order of activity number, e.g., 32BLAB02, 32BLAB04, etc. These numbers are arbitrarily assigned by SPC Planning elements to allow flexibility in tracking and computer manipulation for scheduling of tasks. This is especially valuable in managing numerous tasks which encompass only a portion of an OMI (Operation and Maintenance Instruction). Alpha-plus 4-digit numbers accompanying the Activity number are OMI procedure numbers which contain specific task performance instructions, e.g., S001, B5307, etc.

This resource sample data was derived during planning for mission STS-32 and represents a generic, success-oriented schedule, based on historical data on task accomplishment.

7.5 PROCESSING CRITICAL PATH TASKS AND DURATION

The processing critical path has been extracted and developed from SPC Logic Diagram data which contains notation for "float time," i.e., the time frame in hours during which a task may be scheduled with the flexibility necessary to respond to anomalies and resource availability. A task having zero hours of float time is a "critical path" task and a direct contributor to the minimum scheduled processing timeline. It will appear as a series event in a schedule barchart.

Design attention to critical path items and their elimination/simplification/time reduction is a prime potential source of life cycle cost reduction manifested by reduced processing time, reduced headcount, less facilities and GSE, and (perhaps more important) increased launch rate. The net effect espoused by this study is a potential for dramatic reduction in cost to deliver payload ($/lb) to orbit.

The critical path tasks in Table 7–4 are presented approximately in the order of scheduled accomplishment. The B number is an activity designator arbitrarily assigned by SPC Planning elements to allow ease in tracking and computer manipulation of tasks, many of which encompass only portions of OMIs. Schedule durations are totalled to assist designers in assessing impact of these critical path tasks.

Table 7-1. OEPSS Generic Core Propulsion Stacking Activities, Duration and Manpower

Operation Number	OMI	Activity	Duration (h)	Headcount	Manhours
AB00	OA521	Core propulsion to VAB	4	–	–
AB02	B5303	Stage HDP hardware	6	7	42
AB04	B5303	Disc beam	2	8	16
AB06	B5303	Beam to aisle	2	8	16
AB08	B5303	HDP hardware install	4	7	28
AB10	B5303	HDP tensioner install	4	7	28
AB12	B5303	Tension HDP	12	8	96
AB14	B5303	Tensioner removal	4	7	28
AB16	B5303	Beam preps	20	8	160
AB18	B5303	Core propulsion preps	20	7	140
AB20	B5303	Connect to core propulsion	1	1	1
AB22	B5303	Remove covers/install mod pies	2	2	4
AB34	B5303	Inspect pinholes	1	7	7
AB54	B5303	Bare metal	1	5	5
AB56	B5303	Stack core propulsion	17	8	136
AB58	B5303	Reshim (if required)	6	8	48
AB60	S3001	Configure platforms	1	2	2
AB62	B5303	Mech umbilical connect	6	5	30
AB64	B5307	Elec umbilical connect	6	4	24
AB66	B5303	Zero instrumentation	8	1	8
AB68	B5303	Elec umbilical connect	6	5	30
AB70	B5303	Mech umbilical connect	2	5	10
Total			135		859

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Table 7-2. Resource by Activity (Skill Mix) (Sheet 1 of 2)

STK32: Generic Core Propulsion Stacking
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
32BLAB02	LMQI LMTB LNQI		Stage HDP Hardware	6	1 5 1
32BLAB04	LMS LMQI LMTB LNQI		Disc Beam 05-158-160 (T-22)	2	1 1 5 1
32BLAB06	LMS LMQI LMTB LNQI		Beam to Aisle 05-161-167	2	1 1 5 1
32BLAB08	LMQI LMTB LNQI		HDP Hardware Install T-6	4	1 5 1
32BLAB10	LMQI LMTB LNQI		HDP Tensioner Install	4	1 5 1
32BLAB12	LMS LMQI LMTB LNQI		Tension HDP T-14	12	1 1 5 1
32BLAB14	LMQI LMTB LNQI		Tensioner Removal T-14	4	1 5 1
32BLAB16	LMS LMQI LMTB LNQI		Beam Preps T-22/33	20	1 1 5 1
32BLAB18	LMQI LMTB LNQI		Core Propulsion Preps 05-000-012	20	1 5 1
32BLAB20	LMS		Conn to Core Propulsion 05-013-015 (T-22)	1	1
32BLAB22	LMS LMTB		Remove Covers/Install Mod Pies 07-000-012 (T-34)	2	1 1
32BLAB34	LMQI LMTB LNQI		Inspect Pinholes 07-024-026	1	1 5 1
32BLAB54	LMQI LMTB LNQI		Bare Metal 07-027	1	2 2 1

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Table 7-2. Resource by Activity (Skill Mix) (Sheet 2 of 2)

STK32: Generic Core Propulsion Stacking
Type: Develop Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
32BLAB56	LMS LMQI LMTB LNQI		Stack Core Propulsion 05-016-059	17	1 1 5 1
32BLAB58	LMS LMQI LMTB LNQI		Reshim (If Required) 05-060-120	6	1 1 5 1
32BLAB60	LMS SLC250	S3001	Configure Platforms 05-122 (S3002)	1	1 1
32BLAB62	LMQI LMTB LNQI		Mech Umb Conn 05-121 (T-3A)	6	1 3 1
32BLAB64	LMQI LMTB LNQI	B5307	Elect Umb Conn 05-123 (B5307-1)	6	1 2 1
32BLAB66	LGTB		Zero Instrumentation 05-124-157	8	1
32BLAB68	LMQI LMTB LNQI		Elect Umb Conn 05-171-172 (B5307 T-1)	6	2 2 1
32BLAB70	LMQI LMTB LNQI		Mech Umb Conn 05-173 T-3B	2	1 3 1

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Table 7-3. OEPSS Generic Core Propulsion Stacking – Skill Codes

Code	Skill
LGTB	Technician, instrumentation
LMQI	Quality inspector
LMS	Operations safety
LMTB	Technician, booster (electrical and mechanical)
LNQI	NASA quality inspector
SLC 250	Technician, support (platforms)

Table 7-4. OEPSS Generic Core Propulsion Stacking Critical Path Tasks and Duration

Operation Number	Activity	Duration (h)
–	Core propulsion (LOX/LH_2) processing	–
B00	Core propulsion to VAB	4
B18	Core preps	12
B20	Connect beam to core	2
B56	Stack core	4
B58	Reshim (if required)	8
B60	Configure platforms	2
B62	Mech umbilical connect	14
B64	Elect umbilical connect	6
B66	Zero instrumentation	16
B04	Disconnect beam	2
B08	HDP hardware install	4
B10	HDP tensioner install	4
B12	Tension HDP	12
B14	Tensioner removal	4
Total		94

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8.0 GENERIC CORE TANK ERECT AND MATE

The generic core tank provides expendable propellant storage and supply for the LO_2/LH_2 core propulsion system which is recovered and reprocessed at the launch site. Processing data in this section are extracted from the STS external tank VAB operations and tailored to fit the generic vehicle. Primary operations involve attachment of lifting harness, lift, rotation, mate, and post operations.

8.1 ACRONYMS AND ABBREVIATIONS

ADP	adapter
CONN	connect
CTS	call-to-stations
DISC	disconnect
EB	tank-to-booster attach point
FWD	forward
HB	high bay
HDP	holddown post
OPS	operations
RES	restraint
WAD	Work Authorization Document

8.2 LOGIC DIAGRAM

Figure 8-1 is a Critical Path Method (CPM) logic diagram showing the prime tasks performance sequence for the generic core tank erect and mate with core propulsion and booster(s). Processing starts at the upper left-hand corner with Activity designator ST1000 "start core/booster mate," and continues to the bottom right-hand corner with Activity ST1263 "Forward sling set secure." Numbers at the top center of most task boxes are Work Authorization Document (WAD) numbers of the procedure (Operation and Maintenance Instruction) providing specific task instructions. These activity designators are arbitrarily assigned by Planning elements for tracking and computer manipulation during flow planning. They are especially useful in managing numerous tasks which encompass only part of an OMI.

The number at the top right-hand corner of each task box is the planned duration in hours for that task. Critical path total activity hours are noted in the bottom right-hand key. This duration represents the minimum expected duration of the entire process if no processing anomalies or unscheduled delays are encountered, i.e., a success-oriented schedule based on historical average expected performance. Letters at the beginning and end of each process chain are continuation designators noting tie points of the diagram.

Blank for Foldout

This diagram is intended to provide designers with a simplified view of stage processing tasks to allow comparison with potential new designs, thereby aiding the iterative task of ultimate design simplification, decreased processing time, headcount and facilities, and, perhaps more important, increased launch rate.

8.3 PROCESSING ACTIVITIES, DURATION AND MANPOWER

Table 8–1 is a listing of the tasks in Figure 8–1 showing the additional element of headcount and manhours.

8.4 RESOURCE BY ACTIVITY

The Resource by Activity shown in Table 8–2 is a listing of detail processing tasks which show activity (skill code), WAD number (Work Authorization Document), activity description, activity duration (hours), and quantity (headcount). The skill codes are those used by the SPC and are shown in Table 8–3.

The tabulation in Table 8–2 is presented in alphanumeric order of activity number, e.g., ST1023, ST1033, etc. These numbers are arbitrarily assigned by SPC Planning elements to allow flexibility in tracking and computer manipulation for scheduling of tasks. This is especially valuable in managing numerous tasks which encompass only a portion of an OMI (Operation and Maintenance Instruction). Alpha–plus 4–digit numbers accompanying the activity number are OMI procedure numbers which contain specific task performance instructions, e.g., S0003, S0001, etc. This resource sample data was derived during planning for the generic baseline and is a success–oriented schedule based on historical data on task accomplishment.

8.5 PROCESSING CRITICAL PATH TASKS AND DURATION

The processing critical path has been extracted and developed from SPC logic diagram data which contains notation for "float time," i.e., the time frame in hours during which a task may be scheduled with the flexibility necessary to respond to anomalies and resource availability. A task having zero hours of float time is a "critical path" task and a direct contributor to the minimum scheduled processing timeline. It will appear as a series event in a schedule barchart.

The critical path tasks in Table 8–4 are presented approximately in the order of scheduled accomplishment. The ST number is an activity designator arbitrarily assigned by SPC planning elements to allow ease in tracking and computer manipulation of tasks, many of which encompass only portions of Operation and Maintenance Instructions. Scheduled durations are totalled to assist designers in assessing impact of these critical path tasks.

Design attention to critical path items and their elimination, simplification, or time reduction is a prime potential source of life cycle cost reduction manifested by reduced processing time, reduced headcount, less facilities and GSE, and (perhaps more important) increased launch rate. The net

Table 8–1. OEPSS Generic Core Tank Erect and Mate Processing Activities, Duration and Manpower

Operation Number	OMI	Activity	Duration (h)	Headcount	Manhours
ST1000	-	Start tank/booster mate	-	-	-
ST1023	S0003	Fwd/Aft hardware preps (booster)	16	3	48
ST1033	S0003	Aft restraint install	2	3	6
ST1A33	S0003	Shimpack preps (booster)	4	2	8
ST1053	S0003	Fwd attach inspect	1	2	2
ST1013	S0003	Pre–oper inspect	4	4	16
ST1043	S0003	Fwd sling set preps	4	3	12
ST1A43	S0003	Alignment verif (booster)	1	5	5
ST1063	S0003	Aft hoisting ADP install	1	3	3
ST1A93	S0003	Walkdown inspect HB 2/4	4	4	16
ST1B93	S0003	Walkdown inspect HB 1/3	4	4	16
ST1073	S0003	Remove protective covers	1	3	3
ST1103	S3001	Platform OPS	6	1	6
ST1083	S0003	Install static grounds	1	2	2
ST1113	S0003	CTS/hookdown	–	–	–
ST1123	S0003	Fwd sling preps w/crane	4	9	36
ST1133	S0003	Lift tank from C/O cell	3	17	51
ST1153	S0003	Preps and HDP strain gage meas	1	1	1
ST1143	S0003	Clear controlled area	1	6	6
ST1163	S0003	Position tank between boosters and connect aft restraint	4	16	64
ST1173	S0003	Mate fwd attach points	6	16	96
ST1183	S0003	Soft mate	–	–	-
ST1193	S0003	Tank connect to boosters diagonal	2	16	32
ST1203	S0003	Install fwd hardware	3	16	48
ST1213	S0003	Aft restraint disconnect and remove	2	16	32
ST1223	S0003	Remove fwd sling set	2	16	32
ST1233	S0003	Tank/booster hardware torque	6	16	96
ST1243	S0003	Static ground connect	1	15	15
ST1253	S0003	Lateral strut pinning	6	15	90
ST1263	S0003	Fwd sling set secure	2	16	32
Total			92		774

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Table 8–2. Resource by Activity (Skill Mix) (Sheet 1 of 3)

LMODEL: **Generic Tank/Booster Mate**
Type: **Generic Network**

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
ST1013	LMM LMQ LMS LLET	S0003	Pre–Operations Inspection	4	1 1 1 1
ST1023	LMQ LMTT	S0003	Fwd/Aft Hardware Preps (Booster Pre–Ops 3 and 4)	16	1 2
ST1033	LMQ LMTT	S0003	Aft Restraint Install (Tank Pre–Ops 3)	2	1 2
ST1043	LMQ LMTT	S0003	Fwd Sling Set Preps (Tank Pre–Ops 2)	4	1 2
ST1053	LMQ LMTT	D0003	Forward Attach Insp (Tank Pre–Ops 4)	1	1 1
ST1063	LMQ LMTT	S0003	Aft Hoisting ADP Install (Tank Pre–Ops 5)	1	1 2
ST1073	LMQ LMTT	S0003	Removal of Protective Covers (Tank Pre–Ops 6)	1	1 2
ST1083	LMQ LMTT	S0003	Installation of Static Ground (Tank Pre–Ops 7)	1	1 1
ST1103	SSCC	S3001	Platform Ops	6	1
ST1123	LMQ LMS LMTT SSC250	S0003	Fwd Sling Preps w/Crane (04/00–49)	4	1 1 6 1
ST1133	LMM LMQ LMTT SSC250	S0003	Lift Tank From Checkout Cell (04/50–104)	3	1 5 10 1
ST1143	LMS LMTT	S0003	Clear Controlled Area (05/00–08)	1	2 4
ST1153	SGM	S0003	Preps and HDP Strain Gage Meas Ops (05/09–10)	1	1
ST1163	LMM LMQ LMS LMTT SSC250	S0003	Position Tank Between Boosters and Conn Aft Res (05/11–43)	4	2 2 1 10 1
ST1173	LMM LMQ LMS LMTT SSC250	S0003	Mate Fwd Attach Points EB–1 EB–2 (06/00–43)	6	2 2 1 10 1

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Table 8–2. Resource by Activity (Skill Mix) (Sheet 2 of 3)

LMODEL: **Generic Tank/Booster Mate**
Type: **Generic Network**

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
ST1193	LMM LMQ LMS LMTT SSC250	S0003	Tank Conn to Booster Diagonal Strut (07/00–19)	2	2 2 1 10 1
ST1203	LMM LMQ LMS LMTT SSC250	S0003	Instl Fwd Hardware (08/00–14)	3	2 2 1 10 1
ST1213	LMM LMQ LMS LMTT SSC250	S0003	Aft Rest Disc and Removal	2	2 2 1 10 1
ST1223	LMM LMQ LMS LMTT SSC250	S0003	Remove Fwd Sling Set (10/00–15)	2	2 2 1 10 1
ST1233	LMM LMQ LMS LMTT SSC250	S0003	Tank/Booster Hardware Torque	6	2 2 1 10 1
ST1243	LMM LMQ LMS LMTT	S0003	Static Ground Comm (Post Op 3)	1	2 2 1 10
ST1253	LMM LMQ LMS LMTT	S0003	Lateral Strut Pinning	6	2 2 1 10
ST1263	LMM LMQ LMS LMTT SSC250	S0003	Fwd Sling Set Secure P/O 1 and 2	2	2 2 1 10 1
ST1A33	LMQ LMTT	S0003	Shim Pack Preps (Booster Pre-Ops 5)	4	1 1
ST1A43	LMQ LMTT	S0003	Booster Alignment Verification (Booster Pre-Ops)	1	1 4

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Table 8–2. Resource by Activity (Skill Mix) (Sheet 3 of 3)

LMODEL: **Generic Tank/Booster Mate**
Type: **Generic Network**

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
ST1A93	LMM	S0003	Walkdown Insp HB2/4 (Tank Pre-Ops 8)	4	1
	LMQ				1
	LMS				1
	LLET				1
ST1B93	LMM	S0003	Walkdown Insp HP-1/3 (Tank Pre-Ops 10)	4	
	LMQ				1
	LMS				1
	LLET				1

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Table 8–3. Generic Core Tank Ground Processing – Skill Codes

Code	Skill
LMM	Management
LMQ	Quality
LMS	Operations safety
LMTT	Technician, tank
SGM	Mechanic, GSE support
SSCC	Support, crane controller

effect espoused by this study is a potential for dramatic reduction in cost to deliver payload ($/lb) to orbit.

Table 8–4. Generic Core Tank Erect and Mate Critical Path Tasks and Duration

Operation Number	Activity	Duration (h)
ST1000	Start tank/booster mate	–
ST1023	Fwd/aft hardware preps (booster)	(16)
or		
ST1033	Aft restraint install	2
ST1043	Fwd sling set preps	4
ST1B93	Walkdown inspect HB 1/3	4
ST1103	Platform OPS	6
ST1113	CTS/hookdown	–
ST1123	Fwd sling preps w/crane	4
ST1133	Lift tank from C/O cell	3
ST1143	Clear controlled area	1
ST1163	Position tank between boosters	4
ST1173	Mate fwd attach points	6
ST1183	Soft mate	–
ST1193	Tank connect to boosters diagonal	2
ST1203	Install fwd hardware	3
ST1213	Aft restraint disconnect/remove	2
ST1223	Remove fwd sling set	2
ST1233	Tank/booster hardware torque	6
ST1253	Lateral strut pinning	6
Total		55

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9.0 GENERIC ORBIT VEHICLE LIFT AND MATE

The generic orbit vehicle is a recoverable payload-delivery vehicle having no STS-style MPS. It utilizes STS-equivalent OMS/RCS systems powered by hypergolic propellants. This section outlines the lift, rotation, and mate of the generic orbit vehicle with the core vehicle stack. Processing data in this section are extracted from VAB operations and tailored to fit the generic vehicle. Primary operations involve attachment of lifting harness, lift, rotation, mate, and rollout preparations (some of which are LO_2/LH_2 activities at the core stage).

9.1 ACRONYMS AND ABBREVIATIONS

ACT	activities
CKS	checks
DISC	disconnect
F&D	fill and drain
GHe	gaseous helium
HYD	hydraulics
IF	interface, also I/F
LH_2	liquid hydrogen
LK	leak
LOX	liquid oxygen
MPS	Main Propulsion System
OMS	Orbital Maneuvering System
ORB	orbiter
PLT	plate
QD	quick disconnect
SEP	separation
TBD	to be determined
TSM	tail service mast
WAD	Work Authorization Document

9.2 LOGIC DIAGRAM

Figure 9-1 is a Critical Path Method (CPM) logic diagram showing the prime tasks performance sequence for the generic orbit vehicle lift and mate. Processing starts at the upper left-hand corner with activity designator S0101 "orbit vehicle in transfer aisle," and continues to the bottom left-hand corner with "transfer to pad." Numbers at the top center of most task boxes are Work Authorization Document (WAD) numbers of the procedure (Operation and Maintenance Instruction)

providing specific task instructions. These activity designators are arbitrarily assigned by Planning elements for tracking and computer manipulation during flow planning. They are especially useful in managing numerous tasks which encompass only part of an OMI.

The number at the top right-hand corner of each task box is the planned duration in hours for that task. Critical path total activity hours are noted in the bottom right-hand key. This duration represents the minimum expected duration of the entire process if no processing anomalies or unscheduled delays are encountered, i.e., a success-oriented schedule based on historical average expected performance. Letters at the beginning and end of each process chain are continuation designators noting tie points of the diagram.

The diagram is intended to provide designers with a simplified view of stage processing tasks to allow comparison with potential new designs, thereby aiding the iterative task of ultimate design simplification, decreased processing time, head count and facilities, and, perhaps more import, increased launch rate.

9.3 PROCESSING ACTIVITIES, DURATION, AND MANPOWER

Table 9-1 is a listing of the tasks in Figure 9-1, showing the additional elements of head count and man-hours

9.4 RESOURCE BY ACTIVITY

The Resource by Activity shown in Table 9-2 is a listing of detail processing tasks which show activity (skill code), WAD number (work authorization document), activity description, activity duration (hours), and quantity (head count). These skill codes are those used by the SPC and are shown in Table 9-3.

The tabulation in Table 9-2 is presented in alphanumeric order of Activity No., e.g., S0102, S0104, etc. These numbers are arbitrarily assigned by SPC Planning elements to allow flexibility in tracking and computer manipulation for scheduling of tasks. This is especially valuable in managing numerous tasks which encompass only a portion of an OMI (Operation and Maintenance Instruction). Alpha-plus 4-digit numbers accompanying the Activity No. are OMI procedure numbers which contain specific task performance instructions, e.g., S0004, S0008, etc.

This resource sample data was derived during planning for the generic baseline. It is also based on a success-oriented schedule and on historical data on task accomplishment.

9.5 PROCESSING CRITICAL PATH TASKS AND DURATION

A critical processing path has been extracted and developed from SPC Logic Diagram data which contains notation for "float time," i.e., the time frame in hours during which a task may be scheduled with the flexibility necessary to respond to anomalies and resource availability. A task having zero hours of float time is a "critical path" task and a direct contributor to the minimum scheduled processing timeline. It will appear as a series event in a schedule barchart.

Table 9-1. Processing Activities, Duration, and Manpower

Operation	OMI	Activity	Duration (h)	Head Count	Man-Hours
S0101	–	Orbiter in transfer aisle	–	–	–
S0102	S0004	Connect sling, lift clear of transporter	5	59	295
S0104	S0004	Lift orbiter to core top	2	65	130
S0105	S0004	Orbiter/core soft mate	6	51	306
S0106	S0004	Hard mate	4	50	200
S0107	S0004	Umbilical structural mate	10	28	280
S0109	S0004	Umbilical connect/checkout	14	16	224
S0110	S0004	Umbilical separation closeout	35	22	770
S0201	S0008	Interface test — preparations	8	25	200
S0203	S0008	ORB/core/booster system checks	18	38	684
S0204	S0020	Integrated flight control tests — Part 1	8	24	96
S0205	S0008	Connect core and booster actuators	4	16	64
S0206	S0020	Integrated flight control test — Part 2	2	26	52
S0208	B1019	Core and booster hydraulics disc.	21	14	294
S0301	V1149	T-O Umbilical I/F checks — preparations	16	35	560
S0302	V1149	Hazardous gas system checks	20	35	700
S0303	V1149	T-O umbilicals leak checks	2	35	70
S0304	V1149	Orbiter GHe fill QD leak check	3	21	63
S0306	V1149	LOX F&D QD leak check (booster and core)	8	11	88
S0307	V1149	Blanking plate install (core only)	8	9	72
S0308	V1149	LH_2 fill and drain QD leak check (booster and core)	18	11	198
S0309	V1149	400-psi leak check (core only)	4	9	36
S0310	V1149	Blanking plate removal (core only)	8	9	72
S0311	V1149	Rollout preparations	12	20	240
S0320	V1149	LH_2 flight QD L&F (core only)	18	11	198
		Total	254		5,892

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Table 9-2. Resource by Activity (Skill Mix) (Sheet 1 of 5)

LMODEL: **Orbiter/Core Mate**
Type: **Generic Network**

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
S0102	ENG	S0004	Connect Sling, Lift Clear of Transporter	5	4
	NVM				1
	NENG				4
	SUPV				2
	GSEMT				18
	TPSQC				1
	LSSENG				2
	MOVDIR				1
	SAFETY				2
	TPSENG				1
	TPSSUPV				1
	CNDROPER				4
	CRANCOOD				2
	CRANOPER				4
	LFACTECH				5
	PADLEADR				2
	PHOTOGHR				1
	TPSTECHS				4
S0104	QC	S0004	Lift Orb to Core Top	2	4
	ENG				3
	NQC				3
	NENG				2
	LSSENG				2
	MOVDIR				1
	QCSUPV				1
	SAFETY				2
	CRANCOOD				2
	CRANOPER				2
	LFACTECH				9
	LSOCTECH				30
	PADLEADR				2
	SUPVISOR				2
S0105	QC	S0004	Orb/Core Softmate	6	3
	ENG				6
	NENG				3
	LSSENG				2
	MOVDIR				2
	SAFETY				2
	CRANCOMM				2
	CRANOPER				2
	LFACTECH				9
	LSOCTECH				20
	PADLEADR				2
	SUPVISOR				2

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Table 9-2. Resource by Activity (Skill Mix) (Sheet 2 of 5)

LMODEL: Orbiter/Core Mate
Type: Generic Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
S0106	QC QE ENG NQC NENG LSSENG MOVDIR SAFETY CRANCOOD CRANOPER LSOCTECH PADLEADR SUPVISOR	S0004	Hard Mate	4	4 2 2 3 2 2 2 2 2 3 22 2 2
S0107	QC NQC NENG LAENG LSSENG MOVDIR ELECTENG LFACTECH LSOCSUPV LSOCTECH (STS Orbiter X.5)*	S0004	Umbilical Structural Mate	10*	2 2 2 2 1 2 2 5 3 7*
S0109	QC ENG NQC NENG MOVDIR LSOCTECH (STS Orbiter X.5)* SUPVISOR	S0004	Umbilical Conn/C/O	14*	2 2 2 2 2 5* 1
S0110	QC ENG NQC NENG LSOCQE MOVDIR LSOCTECH SUPVISOR	S0004	Umb Sep Close Out	35	2 2 2 2 2 1 10 1
S0201	QC NQC OICS LSOCTECH	S0008	If Test - Preps	8	4 2 5 14

*STS x 2

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Table 9-2. Resource by Activity (Skill Mix) (Sheet 3 of 5)

LMODEL: **Orbiter/Core Mate**
Type: **Generic Network**

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
S0203	QC ENG NQC NVM NENG OICS LSSENG SAFETY LSOCTECH PADLEADR	S0008	Orb/Core/Booster Systems Checks	18	4 3 2 1 1 5 2 1 17 2
S0204	QC ENG NQC NENG OICS LSSENG SAFETY LSOCTECH	S0020	Integrated Flight Controls Test - Part 1	8	2 2 2 1 5 1 1 10
S0205	QC ENG NQC NENG SUPV LSSENG LSOCTECH	S0008	Connect Core and Booster Actuators	4	2 2 2 1 1 1 7
S0206	QC ENG NQC NENG OICS LSSENG SAFETY LSOCTECH	S0020	Integrated Flight Controls Test - Part 2	2	2 2 2 1 5 1 1 12
S0208	QC ENG NQC NENG SUPV LSOCTECH	B1019	Core and Booster Hydraulics Disconnect	21	2 2 1 1 1 7
S0301	QC ENG NQC NENG OICS SAFETY LSOCTECH PADLEADR	V1149	T-O Umb I/F Cks - Preps	16*	4 3 2 2 5 1 16 2

*STS x 2

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Table 9-2. Resource by Activity (Skill Mix) (Sheet 4 of 5)

LMODEL: Orbiter/Core Mate
Type: Generic Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
S0302	QC	V1149	Haz Gas Cks	20*	4
	ENG				3
	NQC				2
	NENG				2
	OICS				5
	SUPV				2
	LSSENG				2
	SAFETY				1
	LSOCTECH				12
	PADLEADR				2
S0303	QC	V1149	T-O Umbilicals Leak Checks	2*	4
	ENG				3
	NQC				3
	NVM				1
	NENG				2
	OICS				5
	SUPV				2
	LSSENG				2
	SAFETY				1
	LSOCTECH				10
	PADLEADR				2
S0304	QC	V1149	Orb GHe Fill Qd Lk Ck	3	3
	ENG				2
	NQC				2
	NVM				1
	NENG				1
	GSEMT				8
	LSSENG				1
	SAFETY				1
	PADLEADR				2
S0306	QC	V1149	LOX F&D Qd Lk Ck (Booster and Core)	8*	2
	ENG				1
	NQC				1
	NENG				1
	GSEMT				6
S0307	QC	V1149	Blanking Plt Instl (Core Only)	8	1
	ENG				1
	NQC				1
	NENG				1
	GSEMT				4
	LSSENG				1
S0308	QC	V1149	LH_2 F&D Qd Lk Ck (Booster and Core)	18*	2
	ENG				1
	NQC				1
	NENG				1
	GSEMT				6

*STS x 2

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Table 9–2. Resource by Activity (Skill Mix) (Sheet 5 of 5)

LMODEL: Orbiter/Core Mate
Type: Generic Network

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
S0309	QC NQC GSEMT	V1149	400 psi Lk Ck (Core Only)	4	2 1 6
S0310	QC ENG NQC NENG GSEMT LSSENG	V1149	Blanking Plt Removal (Core Only)	8	1 1 1 1 4 1
S0311	LFACTECH	V1149	Roll Out Preps	12	20
S0320	QC ENG NQC NENG GSEMT		LH_2 Flight Qd L&F (Core Only)	18	2 1 1 1 6

*STS x 2

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Table 9-3. OEPSS Generic Orbit Vehicle Lift and Mate – Skill Codes

Code	Skill
CNDR	Support, doors and platforms operator
CRANCOMM	Same as CRANCOOD
CRANCOOD	Crane coordinator (load master)
CRANOPER	Support, crane operator
ELECTENG	Engineer, electrical
ENG	Engineer
GSEMT	Technician, SGE mechanical
LAENG	Engineer, orbiter aft systems
LFACTECH	Support, facility technician
LSOCSUPV	Supervisor, SPC shop
LSOCTECH	Technician, SPC
LSSENG	Engineer, facilities support
MOVDIR	Move director
NENG	NASA engineer
NQC	NASA quality inspector
NVM	NASA vehicle manager
OICS	Engineer, orbiter-integrated checkout system
PADLEADR	Pad leader
PHOTOGHR	Photographer
QC	Quality inspector
QCSUPV	Quality supervisor
QE	Quality engineer (also LSOCQE)
SAFETY	Safety
SUPV	Supervisor
TPSENG	Engineer, TPS
TPSQC	TPS quality inspector
TPSSUPV	Supervisor, TPS shop
TPSTECH	Technician, TPS

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The critical path tasks in Table 9–4 are presented approximately in the order of scheduled accomplishment. The SO number is an activity designator arbitrarily assigned by SPC planning elements to allow ease in tracking and computer manipulation of tasks, many of which encompass only portions of Operation and Maintenance Instructions (OMIs). Scheduled durations are totalled to assist designers in assessing impact of these critical path tasks.

Design attention to critical path items and their elimination, simplification or time reduction is a prime potential source of life cycle cost reduction manifested by reduced processing time, reduced headcount, less facilities and GSE, and (perhaps more important) increased launch rate. The net effect, espoused by this study, is a potential for dramatic reduction in cost to deliver payload ($/lb) to orbit.

Table 9–4. Generic Orbit Vehicle Lift and Mate Critical Path Tasks and Duration

Operation	Activity	Duration (h)
S0101	Orbiter in transfer aisle	–
S0102	Connect sling, lift clear of transporter	5
S0104	Lift orbiter to core top	2
S0105	Orbiter/core soft mate	6
S0106	Hard mate	4
S0301	T–O umbilical interface checks — preparations	16
S0303	T–O umbilicals leak checks	2
S0304	Orbiter GHe fill QD leak check	3
S0320	LH_2 flight QD L&F — booster and core	18
S0306	LOX fill and drain QD leak check	8
S0308	LH_2 fill and drain QD leak check	18
S0311	Rollout preparations	12
–	Transfer to pad	–
	Total	94

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10.0 VEHICLE ROLLOUT TO PAD AND LAUNCH

Rollout and launch processes for the generic vehicle are presented in this section. The data are extracted from equivalent STS/KSC operations. Numerous nonpropulsion activities appear in the section and are noted for reference only in the logic diagrams. The list of activities, duration, and manpower and consistent with previous sections of this volume. However, only about one-third of the head count skill mix data have been developed and the remainder are to be determined in later studies.

10.1 ACRONYMS AND ABBREVIATIONS

BFC	backup
CTS	call-to-stations
DEU	display electronics unit
EMU	extravehicular mobility unit
ET	external tank
FRT	flight readiness test
GND	round
GSE	ground support equipment
H_2O	water
HYD	hydraulics
IMU	inertial measurement unit
LH_2	liquid hydrogen
LO_2	liquid oxygen
MLP	Mobile Launch Platform
MMV	mass memory unit
OMBUU	orbiter mid-body umbilical unit
OMS	Orbital Maneuvering System
PIC	pyrotechnic initiator controller
PPO_2	partial pressure oxygen
PRSD	Power Reactant Supply and Distribution System
QD	quick disconnect
R&R	remove and replace
RCS	Reaction Control System
RIC	Rockwell International Corporation

RSS	Rotating Service Structure
SRSS	Shuttle Range Safety System
SSV	space shuttle vehicle
TCDT	terminal countdown demonstration test
UMB	umbilical
WAD	work authorization document

10.2 LOGIC DIAGRAM

Figure 10–1 is a Critical Path Method (CPM) logic diagram showing the prime tasks performance sequence for the generic vehicle rollout to pad and launch. Processing starts at the upper left-hand corner with Activity designator 28S00001 "preps for rollout," and continues to the bottom right-hand corner of the fourth page with Activity 28S0007 "launch." Numbers at the top center of most task boxes are work authorization document (WAD) numbers of the procedure (Operation and Maintenance Instruction — OMI) providing specific task instructions. These activity designators are arbitrarily assigned by Planning elements for tracking and computer manipulation during flow planning. They are especially useful in managing numerous tasks which encompass only part of an OMI.

The number at the top right-hand corner of each task box is the planned duration in hours for that task. Critical path total activity hours are noted in the center right-hand margin of the first page and shows 618 h. This includes some nonpropulsion series-process hours which impact the critical path and are noted here for reference. Figure 10–1 shows a critical path of 555 h propulsion-related critical path. This duration represents the minimum expected duration of the entire process if no processing anomalies or unscheduled delays are encountered, i.e., a success-oriented schedule based on historical average expected performance. Letters at the beginning and end of each process chain are continuation designators noting tie points of the diagram.

This diagram is intended to provide designers with a simplified view of stage processing tasks to allow comparison with potential new designs, thereby aiding the iterative task of ultimate design simplification, decreased processing time, head count, and facilities, and, perhaps more important, increased launch rate.

10.3 PROCESSING ACTIVITIES, DURATION, AND MANPOWER

Tabl 10–1 is a listing of the tasks in Figure 10–1, showing the additional elements of head count and man-hours. A significant quantity of head count and man-hour information had not developed by the SPC at the time of this study and remain for future activity, if any.

10.4 RESOURCES BY ACTIVITY

The Resource by Activity and the skill codes used by SPC (Table 10–2) are shown in Table 10–3 as a listing of detail processing tasks which show activity (skill code), WAD number (work authorization document), activity description, activity duration (hours), and quantity (head count).

Table 10–1. OEPSS Generic Launch Vehicle Propulsion Systems Processing Activities, Duration and Manpower for Vehicle Rollout to Pad and Launch (Sheet 1 of 2)

Operation	OMI	Activity	Duration (h)	Head Count	Man-Hours
01	A5214	Preparations for rollout	24	20	480
02	A5214	First motion	–	–	–
03	A5214	SSV transfer to pad	8	25	400
05	S0009	Preparations for pad validation	8	47	376
04	A5214	MLP hard down	–	–	–
06	S0009	CTS pad validation	–	–	–
07	S0009	Launch data bus checks	15	5	75
08	S0009	Rotating service structure extend	1	35	35
09	S0009	ORB mid umbilical unit connect	8	10	80
10	S0009	ET GND umbilical carrier plat connect	16	6	96
11	S0009	Vehicle power up	1	1	1
85	S0009	PRSD T–O leak checks	20	TBD	–
12	G2340	ET LOX/LH_2 checkout	16	12	192
13	S0009	OMBUU leak checks	8	8	64
14	S0017	Call to stations TCDT	–	–	–
84	V1149	SEQ 15 QD cavity purge verification	8	TBD	–
15	S0017	Terminal count demonstration test	27	8	216
43	S1805	ET LO_2 purge	16	–	16
16	S0017	Launch demonstration time zero	–	–	–
98	–	Recirculating system leak checks (mass spectrometer)	4	TBD	–
44	S1006	ET LH_2 purge	16	1	16
17	S0017	TCDT securing	5	TBD	–
99	–	Recirculating pump elect. checks (dry spin)	4	TBD	–
18	S0024	Walkdown for hyper load	8	4	32
19	S0024	Call to stations hyper operations	–	–	–
20	S0024	Hypergolics preservice operations	12	37	444
21	S0024	Reaction jet driver test	4	30	120
22	V1045	Oxidizer load	7	33	231
23	V1045	Fuel loading preparations	1	41	41
26	V1036	Auxiliary power unit service	24	34	816
24	B1016	Hydraulic power unit service	12	TBD	–
25	V1045	Fuel load	16	40	640
27	S0024	QD panel closeout	16	33	528
28	S0024	Preparations for RSS retract	7	7	49
29	S0024	RSS retract	1	35	35
30	V1216	Auxiliary power unit hot fire	8	TBD	–

Note: TBD, to be determined. Data base research incomplete. Milestone reference, no headcount assigned.

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Table 10–1. OEPSS Generic Launch Vehicle Propulsion Systems Processing Activities, Duration and Manpower for Vehicle Rollout to Pad and Launch (Sheet 2 of 2)

Opera-tion	OMI	Activity	Duration (h)	Head Count	Man-Hours
31	S0024	Preparations RSS extend	7	7	49
32	S0024	RSS extend	1	TBD	–
42	V1077	Fuel cell coolant ullage adjust	16	10	160
59	V2303	PRSD dewar load, phase 1	12	TBD	–
55	S0024	OMS/RCS QD connect	8	TBD	–
86	–	Hydraulic GSE circ/sample	24	TBD	–
60	V2303	PRSD dewar load, phase 2	8	TBD	–
39	–	Hydraulics connect	8	11	88
40	V1048	SSME's FRT	16	21	336
41	S5009	Vehicle aft closeout	72	24	1,728
51	V1040	PRSD reactant purge, phase 1	12	TBD	–
89	V–078–x	RCS reg. flow	40	TBD	–
38	S5009	Integrated elect. assembly closeout	16	9	144
52	V1040	PRSD reactant purge, phase 2	8	TBD	–
83	–	Planned contingency	120	–	–
53	V1040	PRSD reactant purge, phase 3	8	TBD	–
45	S5009	Vehicle aft closeout, phase 2	48	24	1,152
46	–	Vehicle aft inspection	16	15	240
56	S0024	OMS/RCS pressure to reg. lock-up	8	TBD	–
57	S0024	OMS/RCS pressure to flight mass	8	TBD	–
49	–	Aft access removal	4	16	64
58	S0024	Quick disconnect to panel closeout, phase 1	16	TBD	–
93	S0024	OMS/RCS monitoring	48	TBD	–
50	–	Install flight doors 50–1 and 5–2	4	16	64
66	S0007	Pre-OPS launch countdown	–	–	–
78	–	QD panel closeout, phase 2	–	–	–
67	S0007	CTS launch countdown T–43	–	–	–
68	S0007	Call to stations power-up	4	16	64
78	S0007	Pre-OPS MPS/SSME	4	TBD	–
71	S0007	Built-in hold at T–27 h	8	–	–
72	S0007	PRSD cryo load	8	33	264
73	S0007	Built-in hold at T–19 h	8	–	–
74	S0007	Comm act/switch list	8	TBD	–
75	S0007	Built-in hold at T–11 h	16	TBD	–
76	S0007	Terminal countdown	11	19	209
77	S0007	Launch	–	–	–

Note: TBD, to be determined. Data base research incomplete. Milestone reference, no headcount assigned.

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Table 10–2. OEPSS Vehicle Rollout to Pad and Launch – Skill Codes

Code	Skill
LEEFCPF	Engineer, fuel cell power (firing)
LEETPS	Engineer, TPS
LFS	Safety operations
LNEFCPF	NASA engineer, fuel cell power (firing)
LNQ	NASA quality
LOMMVDR	Move director
LOMOSPV	Management, operations supervisor
LOTFCS	Technician, flight control systems
LOTGSEE	Technician, GSE, electrical
LOTGRED	Technician, GSE, red crew
LOTGSEM	Technician, GSE, mechanical
LOTORBE	Technician, orbiter, electrical
LOTORBM	Technician, orbiter, mechanical
LOTORED	Technician, orbiter, red crew
LOTSCO	Technician, spacecraft operator
LQOOIC	Quality inspector, orbiter integrated checkout
LQQ	Quality, flight element
LSTFAC	Support technician, facilities

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Table 10-3. Resource by Activity (Skill Mix) (Sheet 1 of 7)

SSV28W1: TS to match assmt STS-28
Type: Develop What-if

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
28S00001	LSTFAC POWERDN	A5214	Preps for Rollout	24	20
28S00002	POWERDN	A5214	First Motion	0	
28S00003	LQQ LOTSCO LOTGSEM LOTORBE LOTORBM POWERDN	A5214	SSV Transfer to Pad	8	4 2 4 3 11 1
28S00004	BARCHART	A5214	MLP Hard Down	0	
28S00005	LSF LNQ LQQ LOTSCO LOTGSEM LOTORBE LOTORBM POWERDN	S0009	Preps for Pad Validation	8	1 3 5 3 14 5 16
28S00006	BARCHART	S0009	CTS Pad Validation	0	
28S00007	LQQ LOTGSEM POWERDN	S0009	Launch Data Buss Checks	15	2 3
28S00008	LFS LNQ LQQ LSTFAC LOMMVDR LOTGSEM	S0009	Rotating Service Structure Extend	1	2 3 4 5 1 20
28S00009	LFS LNQ LQQ LOTGSEM LOTORBM	S0009	Orb Mid Umb Unit Connect	8	1 1 2 4 2
28S00010	LNQ LQQ LOTGSEM	S0009	ET Gnd Umb Carrier Plate Connect	16	1 1 4
28S00011	BARCHART	S0009	Space Shuttle Vehicle Power-Up	1	1
28S00012	LNQ LQQ LOTGSEM POWERUP	G2340	External Tank LO_2/LH_2 Checkout	16	1 3 8

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Table 10–3. Resource by Activity (Skill Mix) (Sheet 2 of 7)

SSV28W1: TS to match assmt STS–28
Type: Develop What–if

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
28S00013	LFS LNQ LQQ LOTGSEM POWERUP	S00009	OMBUU Leak Checks	8	1 1 2 4
28S00014	BARCHART	S0017	Call to Stations TCDT	0	
28S00015	LNQ LQQ LOTGSEM POWERUP	S0017	Terminal Count Demonstration Test	27	2 2 4
28S00016	BARCHART	S0017	Launch Demonstration Time Zero	0	
28S00017	POWERUP	S0017	TCDT Securing	5	1
28S00018	LFS LQQ LOTGSEM	S0024	Walkdown for Hyper Load	8	1 1 2
28S00019	BARCHART	S0024	Call to Stations Hyper Operations	0	
28S00020	LFS LNQ LQQ LOTSCO	S0024	Hypergolics Preservice Operations	12	2 4 6 3
28S00020	LQOOIC LOTORBE LOTORBM POWERUP	S0024	Hypergolics Preservice Operations	12	5 3 14
28S00021	LFS LNQ LQQ LOTSCO LQOOIC LOTGRED LOTORED POWERUP	S0024	Reaction Jet Drive Test	4	2 2 2 3 5 8 8
28S00022	LFS LNQ LQQ LQOOIC LOMOSPV LOTGSEM LOTORBM POWERUP	V1045	Oxidizer Load	7	2 4 8 2 1 12 4

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Table 10-3. Resource by Activity (Skill Mix) (Sheet 3 of 7)

SSV28W1: TS to match assmt STS-28
Type: Develop What-if

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
28S00023	LFS LNQ LQQ LOTGSEM LOTORBM POWERUP	V1045	Fuel Loading Preps	1	4 3 6 16 12
28S00024	POWERUP	B1016	Hydraulic Power Unit Service	12	1
28S00025	LFS LNQ LQQ LOTGSEM LOTORBM POWERUP	V1045	Fuel Load	16	4 4 8 12 4
28S00026	LFS LNQ LQQ LOTGSEM LOTORBM POWERUP	V0136	Auxiliary Power Unit Service	24	2 4 8 12 8
28S00027	LQQ LOTGSEM LOTORBE LOTORBM	S0024	QD Panel Closeout	16	7 12 2 12
28S00028	LFS LNQ LQQ LOTGSEM	S0024	Preps for RSS Retract	7	1 1 1 4
28S00029	LFS LNQ LQQ LSTFAC LOMMVDR LOTGSEE	S0024	RSS Retract	1	2 3 4 5 1 20
28S00030	POWERUP	V1216	Auxiliary Power Unit Hot Fire	8	1
28S00031	LFS LNQ LQQ LOTGSEM	S0024	Preps RSS Extend	7	1 1 1 4
28S00032	BARCHART	S0024	RSS Extend	1	1
28S00033	BARCHART	S5009	CTS Ordnance Installation Part 1	0	
28S00034	BARCHART	S5009	SSV Power-Down	1	1

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Table 10-3. Resource by Activity (Skill Mix) (Sheet 4 of 7)

SSV28W1: TS to match assmt STS-28
Type: Develop What-if

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
28S00035	LFS LNQ LQQ LOTGSEE LOTGSEM LOTORBE LOTORBM POWERDN	S5009	SSV Ordnance Installation Part 1	4	1 2 4 2 4 6 3
28S00036	BARCHART	S5009	SSV Power-Up	1	1
28S00037	LSF LNQ LQQ LOTSCO LOTGRED LOTORED POWERUP	S5009	PIC Resistance Checks	4	1 1 3 3 8 8
28S00038	LNQ LQQ LOTGSEM	S5009	Integ Elect Assy Closeout	16	1 1 7
28S00039	LNQ LQQ LOTORBM		Orbiter Hydraulics Connect	8	1 2 8
28S00040	LNQ LQQ LOTGSEE LOTORBE LOTORBM POWERUP	V1040	SSMEs FRT	16	1 2 8 2 8
28S00041	LNQ LQQ LQOOIC LOTGSEM LOTORBE LOTORBM POWERUP	S5009	Orbiter Aft Closeout Phase 1	72	2 2 4 4 2 10
28S00042	LNQ LQQ LOTGSEM LOTORBE LOTORBM POWERUP	V1077	Fuel Cell Coolant Ullage Adjust	16	1 1 5 1 2
28S00043	POWERUP	S1005	External Tank LO_2 Purge	16	1
28S00044	POWERUP	S1006	External Tank LH_2 Purge	16	1

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Table 10-3. Resource by Activity (Skill Mix) (Sheet 5 of 7)

SSV28W1: **TS to match assmt STS-28**
Type: **Develop What-if**

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
28S00045	LNQ LQQ LQOOIC LOTGSEM LOTORBE LOTORBM POWERUP	S5009	Vehicle Aft Closeout Phase 2	48	2 2 4 4 2 10
28S00046	LNQ LQQ LQOOIC LOTORBE LOTORBM		Vehicle Aft Inspection	16	2 2 3 2 6
28S00047	LNQ LQQ LQOOIC LOTORBM POWERUP	V1103	EMU Installation and Test	24	1 2 2 6
28S00048	LNQ LQQ LOTFCS LQOOIC		Crew System Vertical Stowage	12	1 1 4 2
28S00049	LNQ LQQ LQOOIC LOTORBM		Aft Access Removal	4	1 2 3 10
28S00050	LNQ LQQ LEETPS LOMOSPV LOTORBM		Instl Flight Doors 50-1 and 50-2	4	2 2 1 1 10
28S00051	POWERUP	V1040	PRSD Reactant Purge Phase 1	12	1
28S00052	POWERUP	V1040	PRSD Reactant Purge Phase 2	8	1
28S00053	POWERUP	V1040	PRSD Reactant Purge Phase 3	8	1
28S00054	LNQ LQQ LOTORBE POWERUP	V1184	Mass Memory Unit Flight Load	16	1 1 3 1
28S00055	BARCHART	S0024	OMS/RCS QD Connect	8	1
28S00056	POWERUP	S0024	OMS/RCS Press to Reg Lock-up	8	1
28S00057	POWERUP	S0024	OMS/RCS Press to Flight Mass	8	1
28S00058	BARCHART	S0024	Quick Disconnect Panel Closeout Phase 1	16	1
28S00059	BARCHART	V2303	PRSD Dewar Load Phase 1	12	1

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Table 10-3. Resource by Activity (Skill Mix) (Sheet 6 of 7)

SSV28W1: TS to match assmt STS-28
Type: Develop What-if

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
28S00060	BARCHART	V2303	PRSD Dewar Load Phase 2	8	1
28S00061	BARCHART	S5009	CTS Ordnance Instl Part 2	0	1
28S00062	POWERUP	S5009	Shuttle Range Safety System Test	3	1
28S00063	POWERDN	S5009	SSRS Ign Ord Connects	3	1
28S00064	POWERUP	S5009	PIC Resistance Checks	3	1
28S00065	BARCHART	S5009	Ordnance Closeout	12	1
28S00066	BARCHART	S0007	Pre-Ops Launch Countdown	0	
28S00067	BARCHART	S0007	Call to Stations Launch Countdown T-43	0	
28S00068	LNQ LOTSCO LQOOIC LOTGSEE	S0007	Call to Stations Power-Up	4	4 3 5 4
28S00069	LNQ LOTSCO LOTGSEE POWERUP	S0007	BFC Test & MMU/DEU Verification	8	2 3 4 1
28S00070	LNQ LQQ LOTGSEE LOTGSEM	S0007	Pre-Ops MPS/SSME	4	1 3 2 10
28S00070	POWERUP	S0007	Pre-Ops MPS/SSME	4	1
28S00071	POWERUP	S0007	Built-In Hold at T-27 h	8	
28S00072	LNQ LQQ LEEFCPF LNEFCPF LOTGRED LOTGSEM LOTORED POWERUP	S0007	PRSD Cryo Load	8	2 3 2 2 8 8 8
28S00073	POWERUP	S0007	Built-In Hold at T-19 h	8	
28S00074	POWERUP	S0007	Comm Act/Switch List	8	1
28S00075	POWERUP	S0007	Built-In Hold at T-11 h	16	1
28S00076	LOMOSPV LOTGRED LOTORED POWERUP	S0007	Terminal Countdown	11	2 8 8 1
28S00078	BARCHART		QD Panel Closeout Phase 2	0	

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Table 10-3. Resource by Activity (Skill Mix) (Sheet 7 of 7)

SSV28W1: TS to match assmt STS-28
Type: Develop What-if

Activity	Resource	Wad No.	Activity Description	Act. Dur.	Qty.
28S00083	BARCHART	N/A	Planned Contingency	120	
28S00084	POWERUP	V1149	SEQ 15 QD Cavity Purge Verification	8	1
28S00085	BARCHART	S0009	PRSD T-0 Leak Checks	20	1
28S00086	BARCHART		HYD GSE Circ/Sample	24	1
28S00087	BARCHART		SSV Power Down	1	1
28S00088	BARCHART		SSV Power Up	1	1
28S00089	POWERUP	V070-XXX	RCS Reg Flow	40	1
28S00090	POWERUP	V3536	T-20 Day Pot H20 Sample	8	1
28S00091	POWERUP	V1053	PP02 Sensor Instl/Cal	16	1
28S00092	POWERUP	V1043	IMU Calibration	40	1
28S00093	POWERUP	S0024	OMS/RCS Monitoring	48	1

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The tabulation in Table 10–3 is presented in alphanumeric order of activity number, e.g., 28S00001, 28S00002, etc. These numbers are arbitrarily assigned by SPC Planning elements to allow flexibility in tracking and computer manipulation for scheduling of tasks. This is especially valuable in managing numerous tasks which encompass only a portion of an OMI (operation and maintenance instruction). Alpha plus four-digit numbers accompanying the activity number are OMI procedure numbers which contain specific task performance instructions, e.g., A5214, S0009, etc.

This resource sample data was derived during planning for mission STS–28 and represents generic, success-oriented scheduling, based on historical data on task accomplishment.

10.5 PROCESSING CRITICAL PATH TASKS AND DURATION

The processing critical path has been extracted and developed from SPC Logic Diagram data which contains notation for "float time," i.e., the time frame in hours during which a task may be scheduled with the flexibility necessary to respond to anomalies and resource availability. A task having zero hours of float time is a "critical path" task and a direct contributor to the minimum scheduled processing timeline. It will appear as a series event in a schedule bar chart.

The critical path tasks in Table 10–4 are presented approximately in the order of scheduled accomplishment. The activity number is an activity designator arbitrarily assigned by SPC Planning elements to allow ease in tracking and computer manipulation of tasks, many of which encompass only portions of operation and maintenance instructions (OMIs). Scheduled durations are totaled to assist designers in assessing impact of these critical path tasks.

Design attention to critical path items and their elimination, simplification of time reduction is a prime potential source of life cycle cost reduction manifested by reduced processing time, reduced head count, less facilities and GSE, and (perhaps more important) increased launch rate. The net effect espoused by this study, is a potential for dramatic reduction in cost to deliver payload ($/lb) to orbit.

Table 10–4. Rollout to Pad and Launch Processing Critical Path Tasks and Duration (Sheet 1 of 2)

Activity*	Description	Duration (h)
01	Preparations for rollout	24
02	First motion	–
03	SSV transfer to pad	8
05	Preparations for pad validation (parallel to 03) 8 h	–
04	MLP hard down	–
06	CTS pad validation	–
07	Launch data bus	15
11	Space shuttle vehicle power–up	1
13	OMBUU leak checks	8
14	Call to stations TCDT	–
15	Terminal count demonstration test	27
16	Launch demonstration time zero	–
17	TCDT securing	5
18	Walkdown for hyper load	8
19	Call to stations hyper operations	–
20	Hypergolics preservice operations	12
21	Reaction jet driver test	4
22	Oxidizer load	7
23	Fuel loading preparations	1
26	Auxiliary power unit service	24
27	QD panel closeout	16
28	Preparations for RSS retract	7
29	RSS retract	1
30	Auxiliary power unit hot fire	8
31	Preparations RSS extend	7
32	RSS Extend	1
86	Hydraulics GSE circ./sample	24
39	Hydraulics connect	8
40	SSMEs FRT	16
41	Vehicle aft closeout, phase 1	72
83	Planned contingency	120

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Figure 10–4. Rollout to Pad and Launch Processing Critical Path Tasks and Duration (Sheet 2 of 2)

Activity*	Description	Duration (h)
56	OMS/RCS pressure to reg. lock–up	8
57	OMS/RCS pressure to flight mass	8
93	OMS/RCS monitoring	48
68	CTS power–up	4
70	Pre–OPS MPS/SSME	4
71	Built–in hold at T–27 h	8
72	PRSD cryo load	8
73	Built–in hold at T–19 h	8
74	Comm. act/switch list	8
75	Built–in hold at T–11 h	16
76	Terminal countdown	11
77	Launch	–
	Total	555 *

Note: 555 h equates to 69.4 shifts or 23.2 three–shift days.
*Includes 152 h built–in hold/contingency.

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11.0 24-HOUR SCRUB TURNAROUND

This section presents the extremely complex activities performed at KSC in response to a halt of the launch countdown process and a decision to recycle the vehicle and pad activities for a repeat launch attempt the following day. Key activities include critical orbiter cockpit safing, crew egress, drain of cryogenic propellants, and a large spectrum of vehicle and facilities safing actions. The entire scenario is strongly driven by technical considerations associated with cryogenic fluids. The data include a master turnaround logic diagram, a waterfall schedule for sequence of events noting office of primary responsibility, duration of activities, and level of hazard. No attempt was made to define head count and skill mix. Designers can derive much insight into the system-drive chain of events and perhaps devise simpler systems and processes (including attention to countdown termination and recycle requirements).

11.1 ACRONYMS AND ABBREVIATIONS

APU	auxiliary power unit
ASP	activity scheduling program
ATT	attitude
BFS	back-up flight system
BITE	built-in test equipment
CK	check
CMPT	compartment
C/O	checkout
CNTLR	controller
CRYO	cryogenic
CTS	computer test set
CVR	cover
C/W	carrier wave
DDS	Digital Data System
DET	determination
ECS	environmental control system
ET	external tank
ETR	Eastern Test Range
FCE	flight crew equipment
FEP	front end processor
FLT	flight

F/R	firing room
GH_2	gaseous hydrogen
GOX	gaseous oxygen
GN_2	gaseous nitrogen
GVA	GOX vent arm
H_2O	water
HTR	heater
HYD	hydraulic
IMU	inertial measurement unit
INIT	initiate
INSP	inspect
INSTL	install
ISO	isolation
LCC	Launch Control Center
LDA	launch danger area
LDB	launch data bus
LH_2	liquid hydrogen
LOX	liquid oxygen
LPS	launch processing system
LVL	level
MDM	multiplexer/demultiplexer
MECH	mechanical
MED	medical
MLP	Mobile Launch Platform
NTD	NASA test director
O_2	oxygen
OI	operational instrumentation
OMS	orbital maneuvering system
OPR	office of primary responsibility
ORB	orbiter
OTC	orbiter test conductor
PIC	pyrotechnic initiator controller

POS	position
POT	potable
PREPS	preparations
PTC	payload test conductor
PTCR	Pad Terminal Connection Room
PWR	power
RCS	Reaction Control System
REAC	reactivate
REM	remove
RGA	rate gyro assembly
RM	room
SCC	safety console
SEC	security
SEQ	sequence
SF	safe
SPC	shuttle processing contractor
SPKR	speaker
SRB	solid rocket booster
SRSS	Shuttle Range Safety System
SS	sound suppression
STM	shuttle test manager
SUP	suppression
SUPT	support
SW	switching
TBC	tank and booster test conductor
TEMP	temporary
TK	tank
TORQ	torque
U/D	update
VLV	valve
WSB	water spray boiler
WX	weather

11.2 LOGIC DIAGRAM

The logic diagram of Figure 11–1 (A) and (B) is a six–sheet breakdown of the master turnaround logic diagram. It is a graphic presentation of the high degree of operational complexity required to accommodate a launch "scrub." Key activities include critical orbiter safing, crew egress, drain of cryogenic propellants, and a large spectrum of vehicle safing actions in Figure 11–1 (A). Figure 11–1 (A) provides the keys to the diagram layout and task box identifier data. Circled numbers and dashed brackets at the edges of each sheet identify continuity with neighboring sheets in the layout as diagrammed in Figure 11–1 (A). Tasks deemed critical by test management are shown in boxes with heavy outlines.

KEY TO CHARTS

Start scrub

CHART 1	CHART 2	CHART 3
CHART 4	CHART 5	CHART 6

T-O

KEY TO DATA BLOCK

SEQUENCE (OMI NUMBER)

TASK TITLE/DESCRIPTION		
	DURATION	
	FLOAT	

Notes:
1. Start, duration, and float time unit: tenths of hours.
2. Sequence numbers appearing in the four sections: (1) logic diagram, (2) total schedule by office of prime responsibility, (3) total activity schedule, and (4) predecessor/successor report are from developmental data bases and are not entirely consistent with each other.
3. "Float" is the performance window representing the degree of schedule flexibility.

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Figure 11-1 (A). 24-Hour Scrub Turnaround Logic Diagram

11.3 TOTAL SCHEDULE BY OFFICE OF PRIMARY RESPONSIBILITY

The waterfall schedule by office of primary responsibility shown in Figure 11-2 is segregated into four basic areas of (1) NASA test director (NTD), (2) orbiter test conductor (OTC), (3) support test manager (STM), and (4) tank and booster test conductor (TBD). The 120 schedule items reflect emphasis on director/conductor-level concerns. This chart is an end-to-end look at the turnaround process. Time scales at top and bottom are (1) clock time, (2) cumulative hours from start of scrub, and (3) minus hours from the next scheduled T–O (launch).

11.4 24–HOUR SCRUB TURNAROUND TOTAL ACTIVITY SCHEDULE

Figure 11–3 is a waterfall schedule showing the full, continuous sequence of activities without the office segregations of Figure 11–2. The tabulation defines each activity by an associated number and shows its planned duration (ROU) in 1/12–h increments. This chart is also an end–to–end look at the turnaround process. Time scales at top and bottom are (1) clock time, (2) cumulative hours from start of scrub, and (3) minus hours from the next scheduled T–O (launch).

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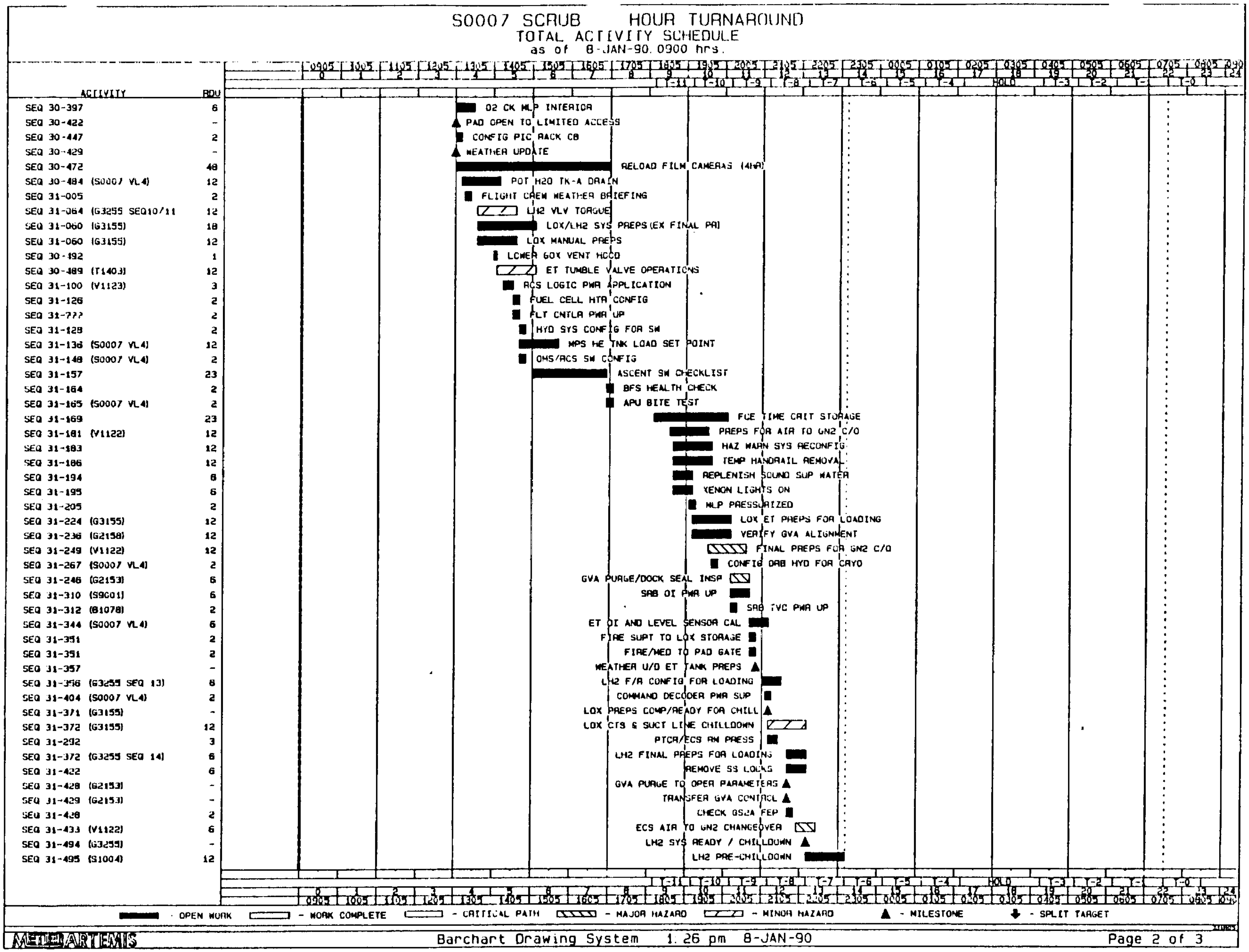

Figure 11-3. 24-h Scrub Turnaround Total Activity Schedule (Sheet 1 of 3)

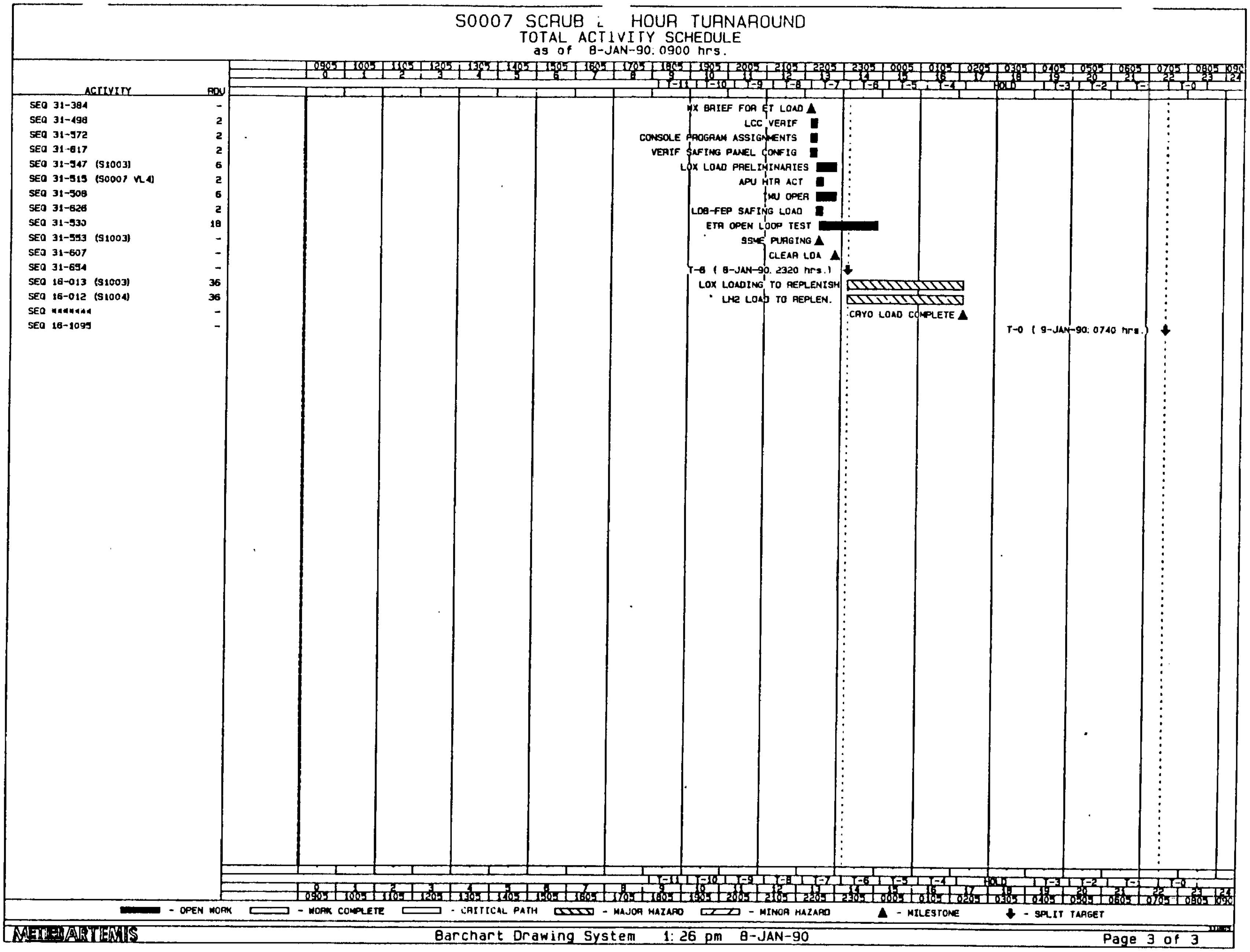

Figure 11-3. 24-h Scrub Turnaround Total Activity Schedule (Sheet 2 of 3)

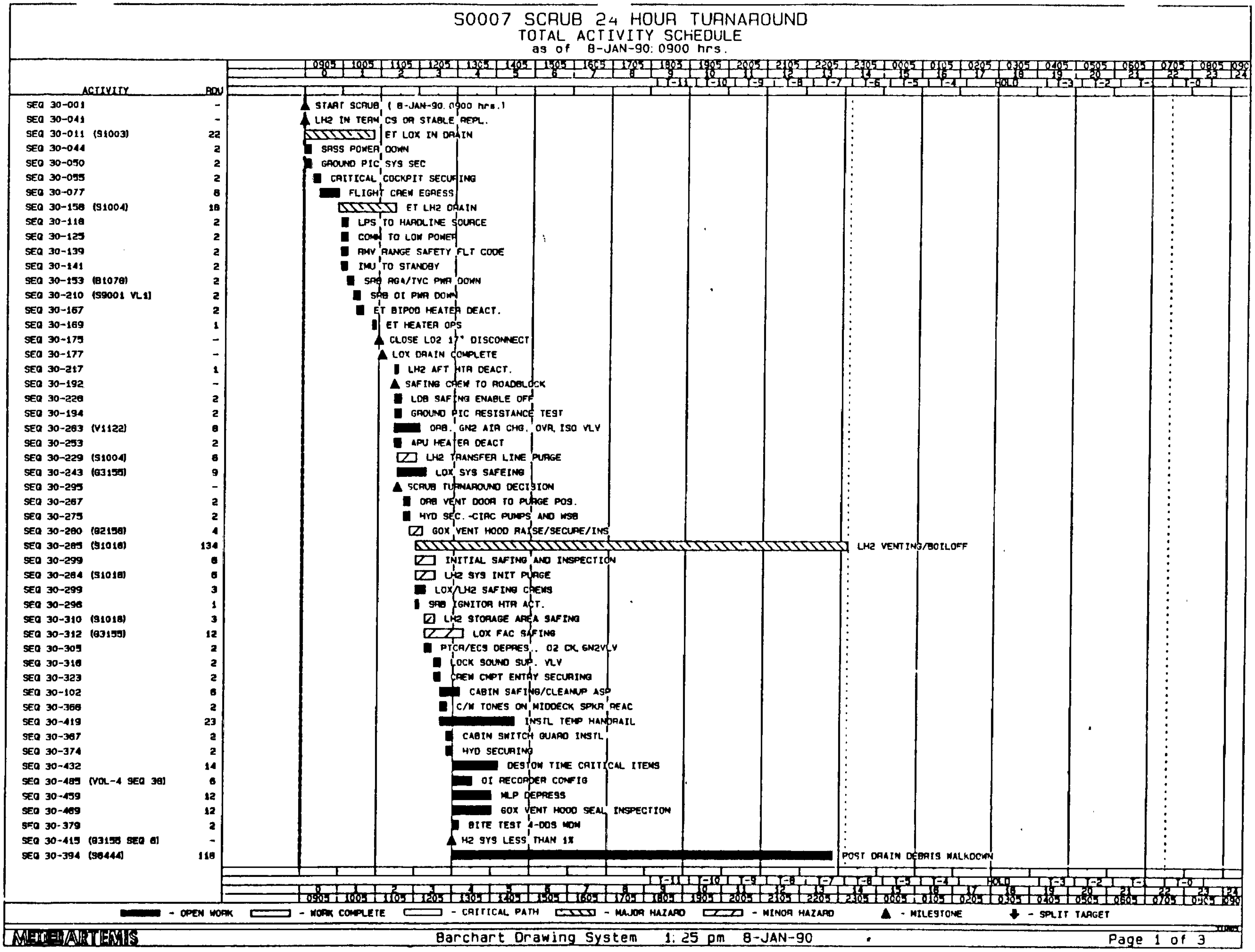

Figure 11–3. 24–h Scrub Turnaround Total Activity Schedule (Sheet 3 of 3)

11.5 PREDECESSOR/SUCCESSOR REPORT

The sequence of activities in Table 11–1 shows the arbitrarily assigned "activity" number and OMI (parentheses). "Event" is also an arbitrarily assigned designator to enable tracking and computer manipulation. "Successor" is the following, or succeeding, event. "Duration" shows activities sequence duration in 1/12–h increments. "Float" is the performance time window, also in 1/12–h increments. Events with 0 float are part of the critical path series operations. The office of primary responsibility is "OPR" where: NTD = NASA test conductor; OTC = orbiter test conductor; STM = support test manager; and TBC = tank and booster test conductor. "System" references the prime system or organization responsibility for the event as follows:

- AFC — airborne flight control
- ASP — airborne systems (cabin)
- BRS — booster pyrotechnics
- CDR — mission commander
- DPS — digital data processing system
- EPD — electrical systems (pyrotechnics)
- HYD — hydraulics
- LCC — launch control center
- LH_2 — liquid hydrogen
- LPS — launch processing system
- MPS — main propulsion system
- ORB — orbiter
- PLT — pilot
- PVD — purge, vent, and drain
- SRB — solid rocket booster
- SRO — range safety officer
- STM — support test manager
- TBC — tank and booster test conductor
- TIF — facilities inspection
- WEA — weather

"Hazard" indicates major or minor level of hazard or area clearance.

Table 11-1. 24-h Scrub Turnaround Predecessor-Successor Report (Sheet 1 of 8)

ACTIVITY	EVENT	SUCCESSOR	DESCRIPTION	DURATION	FLOAT	OPR	SYSTEM	HAZARD
SEQ 30-001	A010		START SCRUB	-	0	NTD	LCC	
	A010	A020		-	11			
	A010	A030		-	11	OTC		
	A010	A140		-	12			
	A010	0020		-	9			
	A010	0030		-	9			
	A010	0040		-	0			
	A010	0080		-	20			
	A010	0090		-	20			
	A010	0100		-	20			
	A010	0110		-	20			
	A010	0120		-	22			
	A010	0130		-	36			
	A010	0180		-	0			
	A010	0260		-	138			
SEQ 30-041	A020		LH2 IN TERM CS OR STABLE REPL.	-	11	TBC	LH2	
	A020	A030		-	11			
SEQ 30-158 (S1004)	A030		ET LH2 DRAIN	18	0	TBC	LH2	MAJOR
	A030	A031		-	0			
	A030	A032		-	75			
	A030	A035		-	1			
	A030	A040		-	16	TBC	LH2	MAJOR
	A030	A050		-	7			
	A030	A060		-	7			
	A030	A170		-	76			
	A030	0130		-	7			
	A030	0160		-	107			
	A030	0170		-	5			
	A030	0180		-	1			
	A030	0190		-	7			
	A030	0240		-	0		ORB	
	A030	0260		-	106			
	A030	0320		-	1			
	A030	0345		-	133			
	A030	0345		-	133			
	A030	0400		-	19		ORB	
	A030	0410		-	105			
	A030	0440		-	89			
SEQ 30-217	A031		LH2 AFT HTR DEACT.	1	0	TBC	PWR	
	A031	A035		-	0			
SEQ 30-167	A032		ET BIPOD HEATER DEACT.	2	75	TBC	PWR	
	A032	A143		-	75			
SEQ 30-229 (S1004)	A035		LH2 TRANSFER LINE PURGE	6	0	TBC	LH2	MINOR
	A035	A040		-	6			
	A035	A050		-	0			
	A035	A060		-	0			
	A035	A070		-	0			
	A035	A170		-	69			
	A035	A170		-	69			

Table 11-1. 24-h Scrub Turnaround Predecessor-Successor Report (Sheet 2 of 8)

ACTIVITY	EVENT	SUCCESSOR	DESCRIPTION	DURATION	FLOAT	OPR	SYSTEM	HAZARD
SEQ 30-310 (S1018)	A040		LH2 STORAGE AREA SAFING	3	6	TBC	LH2	MINOR
	A040	A090		-	92			
	A040	0390		-	6			
SEQ 30-285 (S1018)	A050		LH2 VENTING/BOILOFF	134	0	TBC	LH2	MAJOR
	A050	A131		-	0			
SEQ 30-299	A060		INITIAL SAFING AND INSPECTION	6	0	TBC	SCC	MINOR
	A060	B291		-	77		ORB	
	A060	0320		-	0			
	A060	0400		-	6			
SEQ 30-284 (S1018)	A070		LH2 SYS INIT PURGE	6	0	TBC	LH2	MINOR
	A070	0300		-	79			
	A070	0350		-	4			
	A070	0390		-	0			
SEQ 31-064 (G3255 SE	A090		LH2 VLV TORQUE	12	79	TBC	LH2	MINOR
	A090	A110		-	79			
SEQ 31-356 (G3255 SE	A110		LH2 F/R CONFIG FOR LOADING	6	2	TBC	LH2	
	A110	A120		-	2			
SEQ 31-372 (G3255 SE	A120		LH2 FINAL PREPS FOR LOADING	6	0	TBC	LH2	
	A120	A130		-	0			
SEQ 31-494 (G3255)	A130		LH2 SYS READY / CHILLDOWN	-	0	TBC	LH2	
	A130	A330		-	0			
SEQ 31-654	A131		T-6	-	0	NTD	LCC	
	A131	A290		-	0			
	A131	A340		-	0			
	A131	F990		-	1			
SEQ 30-011 (S1003)	A140		ET LOX IN DRAIN	22	12	TBC	LO2	MAJOR
	A140	A141		-	69			
	A140	A142		-	71			
	A140	A143		-	72			
	A140	A150		-	77			
	A140	A170		-	83			
	A140	0160		-	114			
	A140	0170		-	12			
	A140	0260		-	116			
	A140	0270		-	85			
	A140	0270		-	85			
	A140	0345		-	140			
	A140	0370		-	146			
SEQ 30-169	A141		ET HEATER OPS	1	69	TBC	PWR	
	A141	A142		-	69			
	A141	A150		-	76			
SEQ 30-175	A142		CLOSE LO2 17" DISCONNECT	-	69	OTC	MPL	
	A142	A143		-	69			
	A142	A150		-	75			
SEQ 30-177	A143		LOX DRAIN COMPLETE	-	69	TBC	LOX	
	A143	A150		-	69			
SEQ 30-243 (G3155)	A150		LOX SYS SAFEING	9	69	TBC	LO2	
	A150	A180		-	69			
SEQ 30-299	A170		LOX/LH2 SAFING CREWS	3	69	TBC	LO2	

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Table 11-1. 24-h Scrub Turnaround Predecessor-Successor Report (Sheet 3 of 8)

ACTIVITY	EVENT	SUCCESSOR	DESCRIPTION	DURATION	FLOAT	OPR	SYSTEM	HAZARD
	A170	A180		-	69			
SEQ 30-312 (G3155)	A180		LOX FAC SAFING	12	69	TBC	LO2	MINOR
	A180	A220		-	69			
	A180	A250		-	69			
SEQ 31-060 (G3155)	A220		LOX/LH2 SYS PREPS(EX FINAL PR)	18	65	TBC	LO2	
	A220	A250		-	65			
	A220	A260		-	73			
SEQ 31-060 (G3155)	A250		LOX MANUAL PREPS	12	65	TBC	LO2	
	A250	A260		-	79			
	A250	A265		-	65			
SEQ 31-371 (G3155)	A260		LOX PREPS COMP/READY FOR CHILL	-	0	TBC	LO2	
	A260	A270		-	0			
	A260	B545		-	14			
SEQ 31-224 (G3155)	A265		LOX ET PREPS FOR LOADING	12	10	TBC	LOX	
	A265	A260		-	12			
	A265	A270		-	12			
	A265	B440		-	10			
	A265	B545		-	26			
	A265	B620		-	26			
SEQ 31-372 (G3155)	A270		LOX CTS & SUCT LINE CHILLDOWN	12	0	TBC	LO2	MINOR
	A270	A280		-	2			
	A270	B400		-	14		SRB	
	A270	B490		-	15		SRB	
	A270	B620		-	2			
	A270	B645		-	0			
SEQ 31-547 (S1003)	A280		LOX LOAD PRELIMINARIES	6	0	TBC	LO2	
	A280	A131		-	4			
	A280	A290		-	4			
	A280	B540		-	0		SRB	
	A280	B600		-	4			
SEQ 16-013 (S1003)	A290		LOX LOADING TO REPLENISH	36	0	TBC	LO2	MAJOR
	A290	F666		-	0			
	A290	F990		-	64			
SEQ 31-495 (S1004)	A330		LH2 PRE-CHILLDOWN	12	0	TBC	LH2	
	A330	A131		-	0			
SEQ 16-012 (S1004)	A340		LH2 LOAD TO REPLEN.	36	0	TBC	LH2	MAJOR
	A340	F666		-	0			
	A340	F990		-	64			
SEQ 30-432	B040		DESTOW TIME CRITICAL ITEMS	14	51	OTC	PAD	
	B040	B140		-	51		SRB	
	B040	B150		-	64		SRB	
SEQ 31-005	B050		FLIGHT CREW WEATHER BRIEFING	2	217	NTD	WEA	
	B050	F990		-	217		SRB	
SEQ 30-484 (S0007 VL	B060		POT H20 TK-A DRAIN	12	104	OTC	ECL	
	B060	B540		-	104			
SEQ 30-489 (T1403)	B070		ET TUMBLE VALVE OPERATIONS	12	75	TBC	PAD	MINOR
	B070	B120		-	75		SRB	
SEQ 31-236 (G2158)	B120		VERIFY GVA ALIGNMENT	12	26	TBC	MEC	
	B120	B290		-	26		SRB	

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ACTIVITY	EVENT	SUCCESSOR	DESCRIPTION	DURATION	FLOAT	OPR	SYSTEM	HAZARD
SEQ 31-100 (V1123)	B140		RCS LOGIC PWR APPLICATION	3	50	OTC	OFC	
	B140	B190		-	50		SRB	
	B140	B230		-	52			
SEQ 30-485 (VOL-4 SE	B150		OI RECORDER CONFIG	6	64	OTC	ISL	
	B150	B200		-	64			
SEQ 31-126	B190		FUEL CELL HTR CONFIG	2	50	OTC	FCP	
	B190	B210		-	90		SRB	
	B190	B250		-	50		SRB	
	B190	B270		-	52		SRB	
SEQ 31-128	B200		HYD SYS CONFIG FOR SW	2	50	OTC	HYD	
	B200	B210		-	90		SRB	
	B200	B270		-	50		SRB	
SEQ 31-136 (S0007 VL	B210		MPS HE TNK LOAD SET POINT	12	90	OTC	MPS	
	B210	B655		-	90			
SEQ 31-164	B220		BFS HEALTH CHECK	2	67	OTC	DPS	
	B220	B470		-	67		SRB	
SEQ 31-???	B230		FLT CNTLR PWR UP	2	52	OTC	DPS	
	B230	B270		-	52		SRB	
SEQ 31-148 (S0007 VL	B250		OMS/RCS SW CONFIG	2	50	OTC	OOS	
	B250	B200		-	50			
	B250	B220		-	92			
	B250	B270		-	50		SRB	
	B250	B390		-	74		SRB	
SEQ 31-157	B270		ASCENT SW CHECKLIST	23	48	OTC	ORB	
	B270	B220		-	67			
	B270	B280		-	48		SRB	
	B270	B370		-	62		SRB	
	B270	B380		-	68		SRB	
	B270	B470		-	63			
SEQ 31-169	B280		FCE TIME CRIT STORAGE	23	33	OTC	PAD	
	B280	B540		-	33		SRB	
SEQ 31-246 (G2153)	B290		GVA PURGE/DOCK SEAL INSP	6	26	TBC	MEC	MAJOR
	B290	A290		-	30			
	B290	B520		-	26		SRB	
SEQ 30-305	B291		PTCR/ECS DEPRES., O2 CK,GN2VLV	2	77	STM	MLP	
	B291	0440		-	77		ORB	
SEQ 31-183	B300		HAZ WARN SYS RECONFIG	12	38	OTC	HGD	
	B300	B310		-	38		SRB	
	B300	B320		-	38		SRB	
	B300	B330		-	44		SRB	
	B300	B540		-	38			
SEQ 31-186	B310		TEMP HANDRAIL REMOVAL	12	38	STM	MLP	
	B310	B540		-	38		SRB	
SEQ 31-194	B320		REPLENISH SOUND SUP WATER	6	38	STM	MLP	
	B320	B400		-	38			
	B320	F990		-	148		SRB	
SEQ 31-195	B330		XENON LIGHTS ON	6	44	STM	FAC	
	B330	B540		-	44		SRB	
SEQ 31-205	B340		MLP PRESSURIZED	2	43	STM	MLP	

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ACTIVITY	EVENT	SUCCESSOR	DESCRIPTION	DURATION	FLOAT	OPR	SYSTEM	HAZARD
	B340	B540		–	43		SRB	
SEQ 31-165 (S0007 VL	B370		APU BITE TEST	2	62	OTC	APU	
	B370	B470		–	67		SRB	
	B370	B600		–	69		SRB	
	B370	B610		–	62		SRB	
SEQ 31-181 (V1122)	B380		PREPS FOR AIR TO GN2 C/O	12	25	OTC	PVD	
	B380	B340		–	43		SRB	
	B380	B450		–	25		SRB	
	B380	B490		–	31			
SEQ 31-267 (S0007 VL	B390		CONFIG ORB HYD FOR CRYO	2	16	OTC	HYD	
	B390	A290		–	40			
	B390	A340		–	40			
	B390	B460		–	16		SRB	
SEQ 31-422	B400		REMOVE SS LOCKS	6	8	STM	MLP	
	B400	B540		–	8		SRB	
SEQ 31-344 (S0007 VL	B410		ET OI AND LEVEL SENSOR CAL	6	0	TBC	ISL	
	B410	A270		–	0		SRB	
	B410	B430		–	18		SRB	
SEQ 31-351	B430		FIRE SUPT TO LOX STORAGE	2	18	TBC	LOX	
	B430	A280		–	18		SRB	
SEQ 31-351	B440		FIRE/MED TO PAD GATE	2	4	STM	EGG	
	B440	A260		–	4			
	B440	A270		–	6			
	B440	A280		–	18			
SEQ 31-249 (V1122)	B450		FINAL PREPS FOR GN2 C/O	12	25	OTC	MLP	MAJOR
	B450	B580		–	25		SRB	
	B450	B580		–	25			
SEQ 31-357	B460		WEATHER U/D ET TANK PREPS	–	2	STM	WEA	
	B460	A270		–	2			
SEQ 31-404 (S0007 VL	B470		COMMAND DECODER PWR SUP	2	19	OTC	DPS	
	B470	B540		–	19		SRB	
SEQ 31-292	B490		PTCR/ECS RM PRESS	3	15	STM	MLP	
	B490	B540		–	20		SRB	
	B490	B580		–	15		SRB	
SEQ 30-459	B500		MLP DEPRESS	12	104	STM	MLP	
	B500	B540		–	118		SRB	
	B500	B580		–	104		SRB	
SEQ 31-428 (G2153)	B520		GVA PURGE TO OPER PARAMETERS	–	14	TBC	MEC	
	B520	B530		–	14		SRB	
SEQ 31-429 (G2153)	B530		TRANSFER GVA CONTROL	–	14	TBC	MEC	
	B530	B540		–	14		SRB	
SEQ 31-607	B540		CLEAR LDA	–	0	NTD		
	B540	A290		–	0		SRB	
	B540	A340		–	4		SRB	
	B540	F990		–	104			
SEQ 31-426	B545		CHECK GS2A FEP	2	8	TBC	LPS	
	B545	A280		–	8			
	B545	A340		–	16			
SEQ 31-310 (S9001)	B550		SRB OI PWR UP	6	0	TBC	PWR	

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ACTIVITY	EVENT	SUCCESSOR	DESCRIPTION	DURATION	FLOAT	OPR	SYSTEM	HAZARD
	B550	A290		-	30		SRB	
	B550	A340		-	30		SRB	
	B550	B410		-	0		SRB	
	B550	B560		-	30		SRB	
SEQ 31-312 (B1078)	B560		SRB TVC PWR UP	2	30	OTC	AFC	
	B560	B540		-	30		SRB	
SEQ 31-433 (V1122)	B580		ECS AIR TO GN2 CHANGEOVER	6	9	OTC	MLP	MAJOR
	B580	A290		-	9		SRB	
	B580	A340		-	9		SRB	
	B580	B655		-	9			
SEQ 31-515 (S0007 VL	B600		APU HTR ACT	2	4	OTC	APU	
	B600	A290		-	8			
	B600	A340		-	8			
	B600	B540		-	4		SRB	
SEQ 31-508	B610		IMU OPER	6	0	OTC	DPS	
	B610	B540		-	0		SRB	
SEQ 31-384	B620		WX BRIEF FOR ET LOAD	-	2	STM	WEA	
	B620	A280		-	2			
	B620	B640		-	8		SRB	
	B620	B650		-	8			
SEQ 31-530	B630		ETR OPEN LOOP TEST	18	91	STM	SRO	
	B630	F990		-	91		SRB	
SEQ 31-496	B640		LCC VERIF	2	8	NTD	ALL	
	B640	A131		-	10			
	B640	B650		-	8		SRB	
SEQ 31-572	B645		CONSOLE PROGRAM ASSIGNMENTS	2	0	NTD	ALL	
	B645	A280		-	0			
	B645	A340		-	10			
SEQ 31-617	B650		VERIF SAFING PANEL CONFIG	2	8	NTD	ALL	
	B650	A290		-	10		SRB	
	B650	A340		-	10		SRB	
	B650	B665		-	8			
SEQ 31-553 (S1003)	B655		SSME PURGING	-	9	OTC	MPS	
	B655	A340		-	9			
SEQ 31-626	B665		LDB-FEP SAFING LOAD	2	8	OTC	LPS	
	B665	A290		-	8			
	B665	A340		-	8			
SEQ *******	F666		CRYO LOAD COMPLETE	-	0	TBC	TBC	
	F666	F990		-	0			
SEQ 16-1095	F990		T-0	-	0	NTD	LCC	
SEQ 30-044	0020		SRSS POWER DOWN	2	9	TBC	ORB	
	0020	A030		-	9		ORB	
SEQ 30-050	0030		GROUND PIC SYS SEC	2	9	OTC	BRS	
	0030	A030		-	9		ORB	
SEQ 30-055	0040		CRITICAL COCKPIT SECURING	2	0	OTC	PLT	
	0040	A030		-	6		ORB	
	0040	0050		-	0		ORB	
	0040	0080		-	27		ORB	
	0040	0090		-	27		ORB	

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ACTIVITY	EVENT	SUCCESSOR	DESCRIPTION	DURATION	FLOAT	OPR	SYSTEM	HAZARD
	0040	0100		-	27		ORB	
	0040	0110		-	27		ORB	
SEQ 30-077	0050		FLIGHT CREW EGRESS	6	0	OTC	ORB	
	0050	A030		-	0		ORB	
	0050	0130		-	25		ORB	
	0050	0170		-	23			
SEQ 30-102	0060		CABIN SAFING/CLEANUP ASP	6	0	OTC	ASP	
	0060	B270		-	70			
	0060	0340		-	0			
SEQ 30-118	0080		LPS TO HARDLINE SOURCE	2	20	NTD	ORB	
	0080	0120		-	20		ORB	
SEQ 30-125	0090		COMM TO LOW POWER	2	20	OTC	ORB	
	0090	0120		-	20		ORB	
SEQ 30-139	0100		RMV RANGE SAFETY FLT CODE	2	20	TBC	ORB	
	0100	0120		-	20		ORB	
	0100	0120		-	20		ORB	
SEQ 30-141	0110		IMU TO STANDBY	2	20	OTC	ORB	
	0110	0120		-	20		ORB	
SEQ 30-153 (B1078)	0120		SRB RGA/TVC PWR DOWN	2	20	OTC	AFC	
	0120	0190		-	20		ORB	
	0120	0200		-	98		ORB	
SEQ 30-192	0130		SAFING CREW TO ROADBLOCK	-	7	TBC	LH2	
	0130	A060		-	7		ORB	
	0130	0300		-	92		ORB	
SEQ 30-226	0160		LDB SAFING ENABLE OFF	2	107	NTD	ORB	
	0160	0250		-	107		ORB	
SEQ 30-194	0170		GROUND PIC RESISTANCE TEST	2	5	OTC	EPD	
	0170	A035		-	5			
	0170	0250		-	107		ORB	
SEQ 30-295	0180		SCRUB TURNAROUND DECISION	-	0	NTD	ORB	
	0180	0190		-	0		ORB	
SEQ 30-296	0190		SRB IGNITOR HTR ACT.	1	0	TBC	PWR	
SEQ 30-210 (S9001 VL	0200		SRB OI PWR DOWN	2	98	TBC	PWR	
	0200	B291		-	98		ORB	
	0200	B550		-	116			
SEQ 30-263 (V1122)	0240		ORB. GN2 AIR CHG. OVR,ISO VLV	8	0	OTC	PVD	
	0240	0250		-	106		ORB	
SEQ 30-267	0250		ORB VENT DOOR TO PURGE POS.	2	106	OTC	PVD	
	0250	B410		-	106		ORB	
SEQ 30-275	0260		HYD SEC.-CIRC PUMPS AND WSB	2	106	OTC	HYD	
	0260	B410		-	106		ORB	
SEQ 30-280 (G2158)	0270		GOX VENT HOOD RAISE/SECURE/INS	4	85	TBC	MEC	MINOR
	0270	B410		-	102		ORB	
	0270	0271		-	85		ORB	
SEQ 30-469	0271		GOX VENT HOOD SEAL INSPECTION	12	75	TBC	MEC	
	0271	0272		-	75		ORB	
SEQ 30-492	0272		LOWER GOX VENT HOOD	1	75	TBC	MEC	
	0272	B070		-	75		ORB	
SEQ 30-316	0300		LOCK SOUND SUP. VLV	2	79	STM	MLP	

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ACTIVITY	EVENT	SUCCESSOR	DESCRIPTION	DURATION	FLOAT	OPR	SYSTEM	HAZARD
	0300	0430		-	79		ORB	
SEQ 30-323	0320		CREW CMPT ENTRY SECURING	2	0	OTC	ORB	
	0320	0060		-	0			
	0320	0340		-	2		ORB	
	0320	0350		-	4		ORB	
	0320	0370		-	124		ORB	
	0320	0390		-	4		ORB	
SEQ 30-366	0340		C/W TONES ON MIDDECK SPKR REAC	2	0	OTC	ORB	
	0340	0350		-	0		ORB	
SEQ 30-253	0345		APU HEATER DEACT	2	133	OTC	APU	
	0345	B600		-	133		ORB	
SEQ 30-367	0350		CABIN SWITCH GUARD INSTL.	2	0	OTC	CDR	
	0350	0360		-	51		ORB	
SEQ 30-374	0360		HYD SECURING	2	51	OTC	HYD	
	0360	B040		-	51			
	0360	B410		-	92		ORB	
	0360	0370		-	120		ORB	
SEQ 30-379	0370		BITE TEST 4-DDS MDM	2	120	OTC	DPS	
	0370	A290		-	120		ORB	
	0370	A340		-	120		ORB	
SEQ 30-415 (G3155 SE	0390		H2 SYS LESS THAN 1%	-	0	TBC	LH2	
	0390	0400		-	0			
	0390	0440		-	70			
SEQ 30-394 (S6444)	0400		POST DRAIN DEBRIS WALKDOWN	118	0	TBC	TIF	
	0400	A131		-	4		ORB	
	0400	B540		-	0		ORB	
SEQ 30-397	0410		O2 CK MLP INTERIOR	6	86	NTD	MLP	
	0410	B410		-	86		ORB	
SEQ 30-419	0430		INSTL TEMP HANDRAIL	23	79	NTD	MLP	
	0430	A131		-	103		ORB	
	0430	A270		-	79		ORB	
SEQ 30-422	0440		PAD OPEN TO LIMITED ACCESS	-	70	NTD	SCC	
	0440	A131		-	122		ORB	
	0440	A270		-	98		ORB	
	0440	B300		-	106		SRB	
	0440	B410		-	92		ORB	
	0440	B500		-	104		SRB	
	0440	0271		-	75		ORB	
	0440	0410		-	86		ORB	
	0440	0441		-	90			
	0440	0450		-	217		ORB	
	0440	0470		-	70		ORB	
SEQ 30-447	0441		CONFIG PIC RACK CB	2	90	OTC	EPD	
	0441	B060		-	104			
	0441	B410		-	90			
SEQ 30-429	0450		WEATHER UPDATE	-	217	NTD	WEA	
	0450	B050		-	217		ORB	
SEQ 30-472	0470		RELOAD FILM CAMERAS (4HR)	48	70	STM	STM	
	0470	B540		-	70		ORB	

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